A COMPARATIVE STUDY OF TOOTH ROOT MORPHOLOGY IN THE GREAT APES, MODERN MAN AND EARLY HOMINIDS

by

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(i) Abstract

This thesis sets out to document and analyse some aspects of the metric and morphological variation of tooth roots within the Hominoidea. Samples of the extant species Gorilla gorilla, Pan troglodytes, Pongo pygmaeus and Homo sapiens formed the basis of this study, but fossil hominid specimens from the East African Plio/Pleistocene sites of Koobi Fora, Laetoli, Olduvai and Peninj were also included. The maximum of 182 root, crown and jaw measurements were taken for each specimen included in the comparative samples and included information for all permenent teeth except the maxillary canine. Premolar root number and form were also recorded for each specimen. The corresponding measurements and observations for the mandibular dentition were made, where possible, on the fossil hominid specimens.

The metrical description of tooth roots in the pongids and modern man was accomplished by computing basic descriptive statistics for each measurement and for indices derived from the measurements. These statistical summaries formed the basis of an assessment of root size in the comparative samples. The pattern of sexual dimorphism in root dimensions is presented for each comparative sample, and assessment is also made of the contribution of sexual dimorphism to the variation recorded for root dimensions in the pooled-sex samples. Correlation analysis was used for a preliminary assessment of any inter-relationship between root height and other dimensions.

In the pongid and modern human samples, root number and form were recorded for both maxillary and mandibular premolars,

but in the fossil hominid sample this was possible only for the latter teeth. The assessment of the root and crown dimensions in the fossil hominid sample was conducted by grouping the fossil hominid specimens according to their mandibular premolar root morphology and then examining the dimensions in these fossil hominid groups.

(ii) Acknowledgements

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(iii) Table of contents

(iv) List of tables

(v) List of figures

(vi) List of Appendices

(vii) Introduction

Aspects of tooth crown morphology, particularly crown size, have long been central to many discussions of hominid taxonomy and phylogeny. In contrast, the roots of the teeth have been almost completely ignored as a source of information for hominid studies. The subject of this thesis arose as a response to questions concerning tooth root morphology which were prompted by the discovery of the fossil hominid sample from the site of Koobi Fora, Kenya, a sample which includes many specimens of the lower jaw in which the tooth crowns are missing. Were there features of the tooth roots which could contribute to discussions of hominid taxonomy and phylogeny?

This thesis represents an initial foray into the subject of tooth root morphology in the Hominoidea. Its aims are, firstly, to document aspects of the metric and morphological variation of tooth roots in the great apes and modern man so that, secondly, a realistic attempt may be made at evaluating the corresponding aspects of root morphology in a sample of early fossil hominids. Of particular interest in the comparative samples is the pattern of sexual dimorphism in root size, and the contribution of sexual dimorphism to variability. The evaluation of root form and number was restricted to the premolar region, it being of particular interest as the site of reduction in root number during the course of human evolution.

The thesis is presented in six sections. The first section, the literature review, explores and synthesises published information, firstly, on root development and its

relationship with root morphology, secondly, on root size in the Hominidae - which is mainly restricted to Homo sapiens and covers root surface area and root volume in addition to aspects of linear root dimensions, and thirdly, on the variation of root form and number found within the modern human and early fossil hominid dentitions. The second section describes the comparative and early hominid samples used in the study, and also documents the methodology employed. Included in the latter are outlines of the radiographic method, the assessment of premolar root form, the measurements used and the way in which they were taken, the reliability of the measurement technique, and the statistical procedures used in the analysis of the data. The third section covers the results of the investigation, detailing the root dimensions in the comparative samples, the pattern of sexual dimorphism in the root dimensions of the comparative samples, aspects of inter-relationship between root height and other dimensions, premolar root form in the comparative samples and in the fossil hominid sample, and lastly, the root dimensions in the fossil hominid sample. The fourth section, the discussion, examines these results. The bibliography is presented in the fifth section, and the sixth section comprises the appendices.

Part I : Literature review

Chapter 1 : The developmental basis of root morphology

Chapter 2 : Metrical studies of tooth roots

Chapter 3 : Studies on the variation of root form and number

Part I

Chapter 1 : The developmental basis of root morphology

i) Introduction

ii) The basis of root variation and reduction

Chapter 1 : The developmental basis of root morphology

i) Introduction

Tooth formation starts in the region of the cusp tips and proceeds until the root apex or apices are complete; the developing area of the tooth is mapped out in soft tissue, and then calcification starts. The mapping of the crown is determined mainly by growth of the cervical loop of the enamel organ, and when this is complete, the cervical loop becomes modified and is then known as Hertwig's epithelial sheath. It is this structure which is responsible for the mapping of the root and the initiation of its dentine formation (Bhaskar, 1980; Butler, 1956; Diamond & Applebaum, 1942; Kovacs, 1963, 1967; Osborn & Ten Cate, 1976; Schour & Massler, 1940; Scott & Symons, 1974).

Initially, Hertwig's epithelial sheath bends inwards to form the epithelial diaphragm, this being more or less parallel to the cervical opening of the tooth germ (Bernick & Levy, 1968; Bhaskar, 1980; Grant & Bernick, 1971; Osborn and Ten Cate, 1976; Sicher, 1942). Then, the mapping of the root proceeds through cellular proliferation adjacent and coronal to the epithelial diaphragm, and once an area of the root is mapped, the initiation of dentine formation follows shortly (Bhaskar, 1980; Grant & Bernick, 1971). It is now generally accepted that the epithelial diaphragm maintains a relatively fixed position within the jaw during the greater part of root formation, so that root formation results in movement of the crown towards the alveolar border and thus can be considered to contribute to tooth eruption (Bhaskar, 1980; Diab & Stallard, 1965; Diamond & Applebaum, 1942; Kenney &

Ramfjord, 1969; Kovacs, 1963, 1967; Massler & Schour, 1941; Osborn & Ten Cate, 1976; Sicher, 1942). However, during crown formation there is evidence that the cervical loop grows deeper into the jaw (Carlson, 1944; Diab & Stallard, 1965; Diamond & Applebaum, 1942). These observations contrast with earlier opinion; originally, it was suggested that the developing tooth-edge penetrated into the jaw during crown and root formation (Hertwig, 1874, cited by Diamond & Applebaum, 1942; Prieswerk & Chompret, 1905, cited by Kovacs, 1963), and later, both the cervical loop and its derivative during root formation were thought to maintain a fixed position within the jaw (Orban, 1928; Orban & Mueller, 1929).

The relatively fixed position of the epithelial diaphragm applies only until the crown comes into occlusion; then, the developing root does penetrate into the jaw until the apex is complete (Carlson, 1944; Kovacs, 1964, 1967, 1971; Osborn & Ten Cate, 1976). Kovacs recognises two phases of root development : the eruptive phase, which starts with the beginning of root formation and ends when the crown comes into occlusion, and the penetrative phase, which follows the eruptive phase and continues until the root is complete. Each phase results in a distinctive appearance of the root surface; the root surface formed during the eruptive phase is characteristically smooth, while that formed during the penetrative phase presents a roughened appearance (Kovacs, 1964, 1971, 1979; Romaniuk, 1974). On some roots, the boundary between the two phases is recognizable as a discontinuity or waisting on the root surface, and this feature is particularly noticeable in Neolithic teeth (Kovacs, 1964, 1971, 1979).

Kovacs (1967) considers that during the eruptive phase, the root is protected from environmental influences and is thus under closer genetic control than it is during the penetrative phase, when environmental factors may influence the morphology of the developing root. According to Kovacs, this explains differences of morphology such as that noted for the root surface when the parts of the root formed during the two phases of root development are compared. In addition, he claims that when roots of the same tooth type are compared, they show greater similarity in the parts formed during the eruptive phase than they do in the parts formed during the penetrative phase (Kovacs, 1963, 1964, 1967). While root formation is considered to be under strong genetic control (Ackerman et al, 1973; Moorrees & Kent, 1981), studies have noted the effect of environmental factors - such as nutrition, masticatory function, growth zones and season of birth - on root formation (Ackerman et al, 1973; Brin & Koyoumdijsky-Kaye, 1981; Korkhaus, 1929; Lowe, 1971; Riesenfeld, 1970; Siegel, 1972).

The proportion of the root formed during the eruptive phase of root development appears to vary according to species and according to tooth-type (Gron, 1962; Korkhaus, 1929; Kovacs, 1964, 1971, 1979). In human teeth, the proportion of the root generally formed during the eruptive phase has been estimated as two thirds (Kovacs, 1964), though Gron (1962) observed a higher proportion - generally three-quarters - at a slightly earlier stage of tooth eruption. Both studies agree, however, that the proportion does vary according to tooth type. It may be that the proportion formed during the

eruptive phase decreases from carnivore to omnivore to herbivore (Kovacs, 1971).

During the formation of single-rooted teeth, Hertwig's epithelial sheath maintains a single basal opening - the primary apical foramen - throughout the period of root formation but during the formation of multi-rooted teeth, the primary apical foramen becomes sub-divided into a number of secondary apical foramina (Bhaskar, 1980; Butler, 1956; Gaunt, 1960; Jorgensen, 1950; Kovacs, 1963; Liao, 1979; Osborn & Ten Cate, 1976; Scott and Symons, 1974). The sub-division of the primary apical foramen is effected by processes which develop from Hertwig's epithelial sheath, and these have been variously referred to as the inter-radicular processes, tongues or projections, or as the horizontal processes.

Before the inter-radicular processes develop, their locations are anticipated by the formation of 'bays' in the basal outline during crown formation and the early stages of root formation (Bhaskar, 1980; Butler, 1956; Gaunt, 1960; Osborn & Ten Cate, 1976; Orban & Mueller, 1929). Thus, the inter-radicular processes are initially defined by selective outward expansion of the primary apical foramen. Their subsequent development proceeds through their own active inward growth. The inter-radicular processes grow inwards to the centre of the root, penetrating between the blood vessels as they go, and fuse with each other to form the subpulpal or bifurcal wall (Alexandersen, 1962a, 1963; Bhaskar, 1980; Butler, 1956; Campbell, 1925; Carlsen, 1967; Jorgensen, 1950; Kovacs, 1963, 1967, 1971; Liao, 1979;

Orban & Mueller, 1929; Osborn & Ten Cate, 1976; Scott & Symons, 1974). Each of the secondary apical foramina is formed in relation to blood vessels; prior to the division of the primary apical foramen, the number and locations of the secondary apical foramina are anticipated by the number and locations of the bundles of blood vessels (Aeby, 1878; Cuvier, 1825; Lepkowski, 1897, 1901; all cited by Butler, 1956; Gaunt, 1960). Each of the secondary apical foramina is bounded by a region of Hertwig's epithelial sheath, and so the formation of the separate roots proceeds (Bhaskar, 1980

In calcified specimens, the line of fusion between inter-radicular processes is often identifiable as a ridge on the subpulpal wall and along the adjacent root surfaces (Alexandersen, 1962a; Butler, 1956; Carlsen, 1967; Gher & Vernino, 1980; Kovacs, 1963, 1967, 1971; Lester & Boyde, 1970; Osborn & Ten Cate, 1976; Jorgensen, 1950; Von Brunn, 1887, 1891, cited by Butler, 1956). This ridge has been referred to as the inter-radicular ridge (Kovacs, 1971) or the intermediate bifurcational ridge (Everett et al, 1958) and it is thought to arise from local growth along the line of contact of the processes (Jorgensen, 1950). Though it has a basis in dentine, the ridge is primarily formed of cementum, and it becomes less defined with age probably as a result of secondary cementum formation (Carlsen, 1967; Everett et al, 1958; Kovacs, 1971).

In two-rooted teeth with mesial and distal roots, the inter-radicular ridge runs from the subpulpal wall down the distal surface of the mesial root and down the mesial surface of the distal root; it is usually situated centrally on these

root surfaces and it may be traceable as far as the apex (Everett et al, 1958; Jorgensen, 1950; Kovacs, 1963, 1967). Everett et al (1958) classified the inter-radicular ridge in mandibular first molars by its degree of development, and noted that it was observable in 73% of specimens. In teeth such as maxillary molars, the inter-radicular ridges of the three roots intersect on the subpulpal wall in the form of a Y (Jorgensen, 1950; Kovacs, 1967). The inter-radicular ridge has been identified in animals other than man, an indication that the process of bifurcation is similar in man and other animals (Addison & Appleton, 1928; Butler, 1948; Kovacs, 1971; Lester & Boyde, 1970).

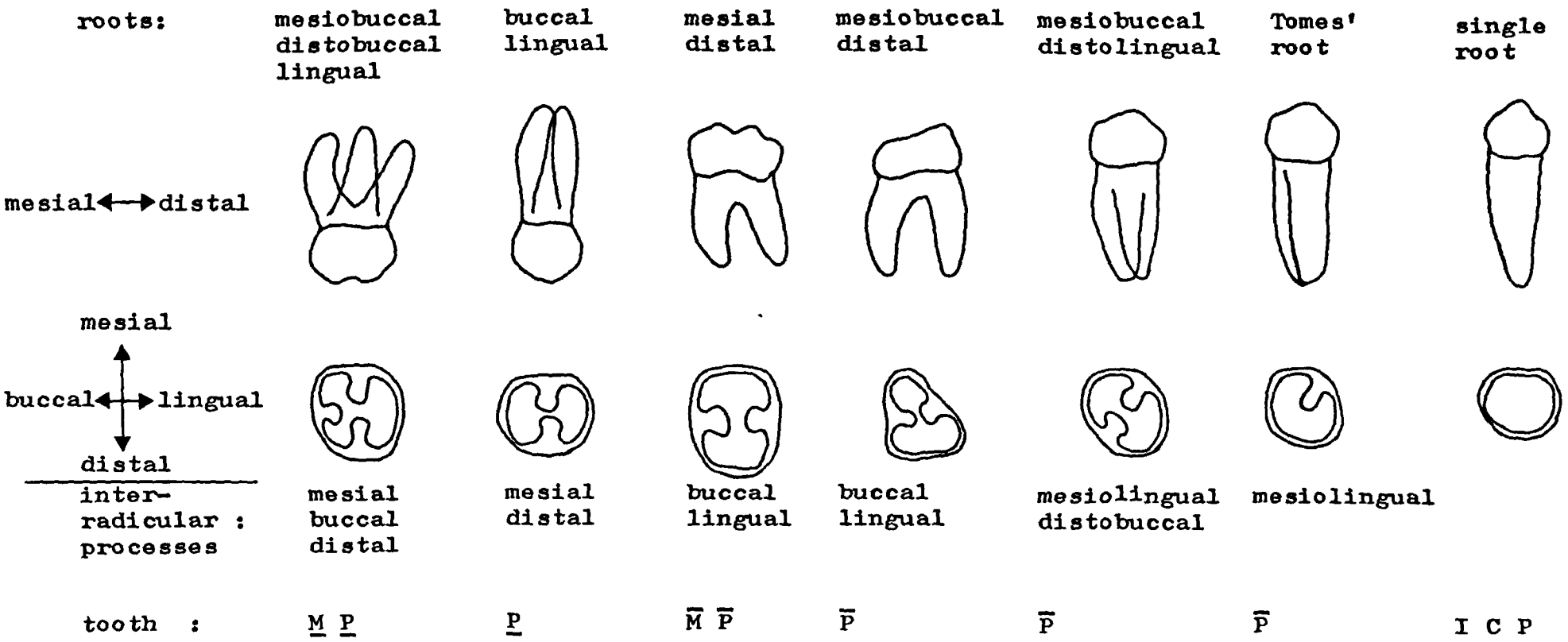
ii) The developmental basis of root variation and reduction

Variation in root form and number (Fig. 1) between teeth of different type and between teeth of the same type but from different specimens or species, is a direct consequence of the variability shown by several factors operating during root development. As succinctly put by Carlsen, (1967):

> "In order to make the variation in ontogenetic root morphology of human teeth intelligible, it is very important that one fully realises that the total variation is in reality identical with the product of the variations of a series of individual factors."

These factors, which are really expressions of the growth process, include: the sites on the primary apical foramen where the inter-radicular processes arise; their number and their relative degree of development; the timing of the appearance of the inter-radicular processes and the timing of their fusion (Carlsen, 1967; Kovacs, 1963, 1967, 1971; Lester & Boyde, 1970).

Fig. 1 : Variation in root form and number between different teeth



The sites where the inter-radicular processes arise on the periphery of the primary apical foramen determine the locations of the tooth roots. In a tooth which will exhibit mesiobuccal, distobuccal and lingual roots, three inter-radicular processes arise and are located on the mesial, distal and buccal borders of the primary apical foramen (Bhaskar, 1980; Jorgensen, 1950). Thus, on fusion, three secondary apical foramina are formed in mesiobuccal, disto-buccal and lingual locations. In a tooth which will exhibit mesial and distal roots, two inter-radicular processes develop - one buccally and one lingually - which form mesial and distal secondary apical foramina on fusion (Bhaskar, 1980; Jorgensen, 1950). The presence of labial/buccal and lingual roots is dependant on the formation and fusion of mesial and distal inter-radicular processes (Alexandersen, 1962a; Carlsen, 1967).

However, root number is dependant not only on the number of the inter-radicular processes, but also on the degree to which they penetrate towards the centre of the primary apical foramen. If all the processes fuse, completely separate roots result; if the penetration of a process is marked, but fusion does not take place, the identity of the two adjacent roots is apparent on the fully-formed specimen although their separation is incomplete; if the penetration is minimal, a superficial root groove results (Alexandersen, 1962a). In this way, a root groove can be seen as the product of an abortive inter-radicular process (Carlsen, 1967). If an inter-radicular process fails to develop there is complete continuity between the 'roots' adjacent to the location of

the absent process. Thus, variation in the development of the inter-radicular processes underlies a continuum of expression of root separation, ranging from complete separation to coalescence of the roots, and suppression of the inter-radicular processes forms a pathway leading to reduction in root number.

The reasons why inter-radicular processes fail to develop, or only penetrate inwards for a short distance, have not apparently been investigated, although it has been suggested that their growth may be blocked by growth of the dental papill or may be inhibited by the proximity of blood vessels (Alexandersen, 1962a; Butler, 1956).

While root formation in molar teeth usually follows its typical course, one or more of the inter-radicular processes may be suppressed, particularly in the second and third molars (Kovacs, 1963, 1967). All the inter-radicular processes may fail to develop and the resulting root form is referred to as a pyramidal root; the molar has a single root which may contain only a single pulp canal and which develops in the same way as that of a typically single-rooted tooth (Kovacs, 1963). A longitudinal root groove or cleft may be present, indicating some degree of development of one or other of the inter-radicular processes. Normal development of at least one, but not all, of the inter-radicular processes leads to the molar root form commonly referred to as fused roots. When this occurs in mandibular molars, there is continuity between the mesial and distal roots on the side where the inter-radicular process has failed to develop - the root and the pulp cavity are horseshoe or crescent-shaped

in cross-section (Kovacs, 1963; Jorgensen, 1950). In maxillary molars, root fusion is frequently encountered and often occurs between the mesiobuccal and lingual roots - in which instance the mesial inter-radicular process has been suppressed to some degree (Jorgensen, 1950). In molars, variability in the development of the inter-radicular processes leads to root forms which are considered atypical; but in premolars such variability leads to the inter- and intra-specific variation documented for the roots of these teeth.

In the pongids, maxillary premolars are generally three-rooted, and mandibular premolars are usually two-rooted, and so the roots develop in the same way as the corresponding molars. Human maxillary premolars, particularly the first, may have one root, two roots or even three roots, and so variation occurs in the number and degree of development of the intra-radicular processes (Carlsen, 1967). Compared with the three-rooted maxillary premolar, the formation of two roots - buccal and lingual - requires only the suppression of the buccal inter-radicular process. In both maxillary and mandibular premolars, the presence of a single root indicates that there is no fusion of inter-radicular processes, though one or more may develop to some degree and so produce longitudinal root grooves.

Under certain circumstances, it is apparent that inter-radicular processes develop which are additional to those required for usual root formation. This is indicated where apical bifurcation occurs in anterior roots, or in premolar and molar roots where it is not the result of suppression

of the usual inter-radicular processes. Two-rooted mandibular canines are quite common in some human populations, and Alexandersen (1962a, 1963) has suggested that these result from the mesial extension of the morphogenetic field which governs root formation in the cheek-teeth.

Up to this point, the description of root development has ignored another major cause of root variation - the relative timing of the fusion of the inter-radicular processes within the period of root formation. The level at which the inter-radicular processes fuse determines the height of bifurcation (Carlsen, 1967); this may be close to the cervical line so that the root body shows little depth, or it may be delayed resulting in a deeper root body. Delay in fusion of the inter-radicular processes partly explains human maxillary premolar root variation (Carlsen, 1967), and can also be seen at work in the formation of taurodont molars. In the latter, fusion of the inter-radicular processes may be so delayed that the separate roots, or even just the subpulpal wall, are present only in the most apical region (Kovacs, 1963, 1964).

The direction of growth of the inter-radicular processes determines the contours of the subpulpal wall (Alexandersen, 1962a, 1963; Carlsen, 1967; Kovacs, 1971). When this is more or less horizontal then the subpulpal wall will be approximately horizontal, but if the inter-radicular processes grow both inwardly and apically, so that the level of fusion is apical to the level at which they arise, then the subpulpal wall will slope. The degree of this slope depends on the rate

of apical growth relative to the rate of inwards growth. While the timing of fusion of any two inter-radicular processes is *per se* the same, the timing of their initial development is not necessarily simultaneous so that the subpulpal wall may show differing slope in its different parts (Carlsen, 1967).

Another feature of the inter-radicular processes which underlies variation in root form is their shape. The width of the inter-radicular processes determines whether the roots will be well-separated or closely apposed, and their shape determines the shape of the subpulpal wall and helps determine the contours of the root surfaces adjacent to the subpulpal wall (Alexandersen, 1962a, 1963; Carlsen, 1967; Kovacs, 1963, 1971).

This survey of root development has identified a variety of factors which underlie variation in root form and number. It has also indicated the probable developmental pathways of root reduction; as recognised by Jorgensen (1950), root reduction can be effected through increasing suppression of the inter-radicular processes or through delay in their fusion. Additionally, it can be seen that change in root form can be produced by change in the siting of the inter-radicular processes on the primary apical-foramen, and also by change in the contours of the primary apical foramen which itself may reflect changes in crown shape. The examination of premolar root form in the hominid fossils may prove to be a particularly fruitful source of information which has relevance to the study of hominid phylogeny.

Part I

Chapter 2 : Metrical studies of tooth roots

i) Linear root dimensions

ii) Relative root height

iii) Correlational studies on root dimensions

iv) Root surface area and volume studies

Chapter 2 : Metrical studies of tooth roots

While the crowns of the teeth have been the subject of many and various metrical studies, the size of tooth roots has received little attention - a result, no doubt, of their usual inaccessibility within the jaws. However, relative to the paucity of published information available for the pongids and fossil hominids, a wealth of information exists with regard to the human dentition. As far as the pongids are concerned, studies concerning the metrical aspects of tooth roots are virtually non-existent, and for the hominids, information is mainly restricted to the reporting of tooth root measurements - the size of tooth roots has played little part in taxonomic or phylogenetic discussion. For these reasons, the following survey of root size is mainly restricted to the modern human dentition.

i) Linear root dimensions

With a few exceptions, measurements of root size in the fossil hominids have been published with little in the way of accompanying comment; and so, apart from a few observations, root size in the hominids will not be discussed here, but later where comparison will be made with the results of this investigation. Published root measurements for the fossil hominids have been collected together in Appendix L.

In a study on the postcanine dentition of the South African fossil hominids (Sperber, 1974), measurement was

made where possible of root height, root mesiodistal diameter and root buccolingual diameter. Generally, the mean values for these dimensions in the Swartkrans australopithecines were greater than in the Sterkfontein specimens, being statistically significantly different for some dimensions : for P^4 mesiobuccal root height ($P = 0.05$), for M^2 mesiobuccal and distobuccal root heights ($P = 0.05$), for all M^3 root heights ($P = 0.01$) and for all dimensions of M_3 ($P = 0.05$) except the mesiodistal diameter of the distal root.

In an experimental study on masticatory function in the Hadar hominids (Ward & Molnar, 1980), the mesial area of a mandibular molar sustained greater force than the distal area, and this was suggested to be compatible with observed mandibular molar morphology. In the Hadar hominids, and in some specimens referred to *Australopithecus robustus* and *A.africanus*, the mesial root of a mandibular molar is buccolingually broader and more robust than the distal root (Ward & Molnar, 1980; Ward *et al*, 1982). Similar root morphology has been described for some Laetoli (White, 1977) and, as just noted, South African hominid mandibular molars (Robinson, 1956; Sperber, 1974). Of the mandibular molars, M_2 has generally the largest roots in the Hadar hominids (Ward, 1979) and in South African hominids (Sperber, 1974).

Weidenreich (1937) has made observations on root height in *Homo erectus pekinensis*. In both jaws the canine has the longest root, but while in modern man the root height of the maxillary canine is typically greater than that

of the mandibular tooth, in this hominid group the converse applied. When compared with Homo erectus, root height in modern man shows much greater reduction anteriorly (I1 to P3) than posteriorly (P4 to M3), and this, Weidenreich (1937) suggested, is related to the reduction of the anterior part of the face in modern man.

For the modern human dentition, the measurement of root size has been mainly limited to root height. (Throughout this thesis, the term 'root height' is used in preference to 'root length' as it is compatible with the accepted labelling of crown dimensions). The published mean values of root height in human populations are presented in Table 1 (mandibular dentition) and Table 2 (maxillary dentition). As slightly different methods of measuring root height were used in some studies, not all the mean values are exactly comparable. In addition to root height, projected root height, computed root height and root width have been measured for the postcanine dentition of American Whites and Negroes (Moss et al, 1967), and neck mesiodistal diameter for American Whites (Black, 1902) and Eskimos (Ritchie, 1922-23). In an American sample, the root mesiodistal diameter of the apical, middle and cervical thirds was measured for all roots except those of the second and third molars, and with the exception of the M_1 lingual root where root buccolingual diameter was measured (Tilk et al, 1979)

Mongoloid peoples tend to have shorter roots than other human groups, especially when root height is related to crown

Table 1 : Published mean values of mandibular root height in modern man

	I_1	I_2	C_1	P_3	P_4	M_1	M_2	M_3	Reference
Teso of Uganda	13.2	13.5	15.9	17.0	16.6	15.2	15.5	15.4	Barnes, 1969
Bantu	12.4	13.2	17.0	15.0	15.2	13.5	13.5	12.0	Shaw, 1931
Bantu	12.8	13.7	16.1	15.0	15.3	13.0	12.9	13.3	Drennan, 1929
Bushman	12.0	13.4	15.3	14.1	14.8	12.4	13.1	12.5	Drennan, 1929
American Negro s/m	-	-	-	14.4	15.8	15.0	15.9	14.7	Moss et al, 1967
d	-	-	-	-	-	14.9	15.2	13.0	" "
American Whites s/m	-	-	-	14.8	15.3	15.5	15.3	13.6	" "
d	-	-	-	-	-	14.7	14.6	12.6	" "
American Whites	11.8	12.7	15.3	14.0	14.4	13.2	12.9	11.8	Black, 1902
British	14.5	14.0	15.0	11.0	15.0	14.0	14.0	13.0	Taylor, 1899
Prehistoric French	13.0	12.4	14.6	14.3	15.8	-	13.5	-	Brabant et al, 1961
Calvinia & Namqualand	12.2	13.0	16.8	15.0	15.1	13.4	13.3	12.1	Abrahams, 1946-47
Norwegian Lapps	12.6	14.1	16.0	14.4	15.5	13.7	14.2	13.0	Selmer-Olsen, 1949
East Greenland Eskimo	-	-	16.6	13.5	13.2	13.2	12.5	11.7	Pedersen, 1949
Eskimo	12.2	13.6	16.6	13.5	13.0	13.5	12.7	13.7	Ritchie, 1922-23
Aleutians	8.9	11.0	-	12.4	13.3	12.3	-	-	Moorrees, 1957
Pecos Pueblo Indians	11.9	12.4	15.3	13.4	14.5	13.6	13.8	12.6	Nelson, 1938
Japanese	9.7	11.6	13.6	12.2	12.8	12.1	11.3	10.5	Miyabara, 1916
Australian Aborigine	13.4	14.7	18.1	16.3	16.5	14.2	15.0	14.0	Campbell, 1925

s-single; m-mesial; d-distal;

Table 2 : Published mean values of maxillary root height in modern man

	I^1	I^2	C^1	P^3	P^4	M^1	M^2	M^3	Reference
Teso of Uganda	13.8	13.7	17.9	15.0	16.4	15.2	14.9	13.7	Barnes, 1969
Bantu	13.4	13.6	17.3	13.9	14.6	13.5	12.5	11.5	Shaw, 1931
Bantu	13.5	13.5	16.1	14.9	14.6	12.5	10.0	12.6	Drennan, 1929
Bushman	12.5	12.5	16.3	14.5	14.8	11.6	12.6	12.6	" "
American Negro l/s	-	-	-	13.5	15.5	13.1	13.4	12.3	Moss et al, 1967
b/mb	-	-	-	13.9	-	12.7	13.4	12.9	" " "
db	-	-	-	-	-	11.9	12.4	11.1	" " "
American Whites l/s	-	-	-	14.0	14.3	14.5	14.1	12.5	" " "
b/mb	-	-	-	13.5	-	13.6	12.9	12.3	" " "
db	-	-	-	-	-	12.5	12.5	11.2	" " "
American Whites	12.0	13.0	17.3	12.4	14.0	13.2	13.0	11.4	Black, 1902
British	14.5	14.7	18.0	14.0	15.0	15.0	13.0	14.0	Taylor, 1899
Prehistoric French	13.0	12.4	14.6	14.3	15.8	-	13.5	-	Brabant et al, 1961
Calvinia & Namqualand	13.3	13.5	17.2	13.8	14.4	13.5	12.7	11.5	Abrahams, 1946-47
Norwegian Lapps	12.1	12.3	16.9	14.1	14.7	13.5	13.9	12.5	Selmer-Olsen, 1949
East Greenland Eskimo	-	-	16.3	13.1	13.6	12.7	12.3	12.0	Pedersen, 1949
Eskimo	13.1	14.0	16.4	13.2	13.2	10.5	11.8	13.1	Ritchie, 1922-23
Aleutians	11.1	11.6	-	12.3	12.6	12.5	-	11.3	Moorrees, 1957
Pecos Pueblo Indians	12.9	12.5	15.5	13.0	13.3	13.2	12.9	12.2	Nelson, 1938
Japanese	11.3	11.7	14.9	12.2	12.9	13.2	13.1	10.5	Miyabara, 1916
Australian Aborigine	14.6	15.6	20.0	16.3	16.9	13.5	13.6	13.9	Campbell, 1925

s-single; l-lingual; mb-mesiobuccal; db-distobuccal; b-buccal

size (Nelson, 1938; Pedersen, 1949; Todd, 1915; Tratman, 1950). In the Pecos Pueblo Indians, this relative shortness of the roots was least apparent in the molars (Nelson, 1938). Pedersen (1949) suggested that the short roots of the East Greenland Eskimo were the result of apical resorption in response to heavy occlusal stress and attrition, but Tratman (1950) has disagreed with this opinion on several counts and has proposed that short roots should be considered characteristic of the Mongoloid race. For the most part, the Australian Aborigines (Campbell, 1925) and the Bantu (Drennan, 1929; Shaw, 1931) show greater root height than other human groups (Pedersen, 1949), though clearly not greater than the Teso of Uganda (Barnes, 1969). Root height in Caucasian groups tends to be intermediate between that of the Australian Aborigines/Bantu and that of the Mongoloids (Tratman, 1950). However, Selmer-Olsen (1949) has suggested that long molar roots are characteristic of the Norwegian Lapps as, in comparison to crown size, molar root height is greater in this group than in other human groups. When the postcanine dentitions of American Whites and Negroes were compared (Moss *et al*, 1967), root height was found to be similar though the former group did show a greater mean value for M^1 root height ($P < 0.05$) and the latter group for M_3 mesial root height ($P < 0.05$). Differences between these two groups were also documented for other root dimensions The American Negroes showed greater mean values for the buccolingual root widths of P_3 ($P < 0.01$), the M_2 distal root ($P < 0.05$) and the M^2 distobuccal root ($P < 0.05$), while the American Whites did so for the M_1 mesial root ($P < 0.05$). In addition, the values of ratios relating buccolingual root

width to root height indicated that the maxillary postcanine roots of the American Negroes were more robust than those of the American Whites, while for certain mandibular postcanine roots, notably P_4, the more robust roots were displayed by the American Whites.

Very little attention has been given to the examination of sexual dimorphism in root dimensions. Male and female mean values of root height (Table 3) have been reported for the Japanese (Miyabara, 1916), the East Greenland Eskimo (Pedersen, 1949), and the Norwegian Lapps (Selmer-Olsen, 1949). In the East Greenland Eskimo, no systematic sexual differences were observed in root height, but in many instances the sample sizes were particularly small (Pedersen, 1949). In the Norwegian Lapps, root height was found to exhibit more sexual dimorphism than either crown buccolingual diameter or crown mesiodistal diameter, being more marked in the mandibular teeth than in the maxillary and more marked in the anterior teeth than in the molars (Selmer-Olsen, 1949). Similar observations have been made on an American sample (Garn *et al*, 1978b), where sexual dimorphism in root height for C_1 to M_2 was found to be greater than sexual dimorphism in the corresponding crown diameters. These indications of greater sexual dimorphism in root height led Garn *et al* (1979) to investigate the effectiveness of root height in sexual attribution, and they found that, for C_1 to M_2, root height was generally as effective, or more effective, than either of the crown diameters. Of the five teeth, the root height of the canine showed the highest success in determining sex and resulted in correct attribution in 70% of cases.

Table 3 : Published male and female mean values of root height in modern man

		I1	I2	C	P3	P4	M1	M2	M3	Reference
Mandibular										
Japanese	male	8.8	12.1	14.0	12.4	13.3	12.2	12.1	11.6	Miyabara, 1916
	female	10.6	11.2	13.2	12.0	12.3	12.0	10.4	9.4	
E.G.Eskimo	male	-	-	16.9	13.1	13.8	13.4	13.1	11.5	Pedersen, 1949
	female	-	-	16.1	14.0	12.4	12.4	11.7	12.2	
Norwegian Lapps	male	13.2	14.7	16.7	14.8	16.0	14.1	14.7	13.2	Selmer-Olsen, 1949
	female	12.0	13.5	15.2	14.0	15.0	13.3	13.9	12.7	
Maxillary										
Japanese	male	11.8	12.2	15.4	12.2	13.6	13.9	12.5	10.8	Miyabara, 1916
	female	10.9	11.2	14.3	11.3	12.2	12.4	13.8	10.1	
E.G.Eskimo	male	-	-	17.3	14.1	13.5	12.9	12.1	12.1	Pedersen, 1949
	female	-	-	14.8	11.1	14.0	12.4	12.5	11.1	
Norwegian Lapps	male	12.9	13.3	17.6	14.7	15.3	13.6	14.1	12.8	Selmer-Olsen, 1949
	female	11.5	12.5	16.4	13.6	14.2	13.4	13.6	12.2	

However, a greater degree of correct sexual attribution - 84% - resulted from a total of thirteen measurements which included crown dimensions as well as root heights. A success rate nearly as good as this - 82% - was achieved using the six dimensions of just two teeth - the $C_{\overline{1}}$ and $M_{\overline{2}}$.

The canine has the longest root within each jaw, and the maxillary canine has the longest root of the whole dentition (Black, 1902; Diamond, 1952; Kraus et al, 1969; Scott & Symons, 1974; Tomes, 1923). In the Teso of Uganda (Barnes, 1969), the mean, minimum and maximum values of $P_{\overline{3}}$ root height were greater than the corresponding values of $C_{\overline{1}}$ root height, but these results may well stem from small sample size. Root height in the two maxillary incisors is generally similar (Kraus et al, 1969; Scott & Symons, 1974), while $I_{\overline{2}}$ typically shows greater root height than $I_{\overline{1}}$ (Abrahams, 1946-47; Diamond, 1952; Nelson, 1938; Shaw, 1931; Tomes, 1923). In both jaws, the height of the second premolar root is usually greater than that of the first (Abrahams, 1946-47; Black, 1902; Diamond, 1952; Selmer-Olsen, 1949; Tomes, 1923), and when the $P^{\underline{3}}$ is two-rooted, the buccal root is larger in all dimensions than the lingual (Diamond, 1952). In both maxillary and mandibular molars, the third molar typically has the shortest roots (Black, 1902; Kraus et al, 1969; Scott & Symons, 1974; Tomes, 1923). Within each maxillary molar, lingual root height is usually greater than mesiobuccal root height, which is usually greater than distobuccal root height, and the distal root of each mandibular molar is usually narrower buccolingually than the mesial root (Black, 1902; Diamond, 1952; Kraus

et al, 1969; Scott & Symons, 1974; Tomes, 1923). In comparison to root height, for I1 to M1 root mesiodistal diameter generally shows a similar pattern of size difference between the roots with the notable exception that the $I^{\underline{1}}$ root is larger than the $C^{\underline{1}}$ root (Tilk et al, 1979).

In multi-rooted teeth, the height of bifurcation - the distance between the summit of the bifurcation and the cementoenamel junction - may differ according to the side on which it is measured, and in teeth with more than two roots, it may differ between the pairs of roots (Kovacs, 1971). In order to allow better comparison between zoological groups, Kovacs (1971) has suggested the use of the height of bifurcation index, which relates the height of bifurcation to total tooth height. However, owing to the effect of occlusal wear on crown height, it should be considered preferable to relate height of bifurcation to root height. In the Teso of Uganda, wide variation has been noted in the proportion of root height which is occupied by the height of bifurcation (Barnes, 1969). Quantification of the height of bifurcation is particularly applicable to the examination of taurodontism, and this will be discussed later.

In comparison to the crown mesiodistal and buccolingual diameters, root height tends to show greater variation (Barnes, 1969; Tratman, 1950); in the Norwegian Lapps, the average value of the coefficients of variation for root height was about 12.0, while those for the crown diameters were about 7.0 (Selmer-Olsen, 1949). The only other study in which coefficients of variation are reported for large sample size is that on the Pecos Pueblo Indians (Nelson, 1938),

where the average of the coefficients of variation for root height - about 9.0 - appears lower than in the Norwegian Lapps.

The roots of certain teeth may be particularly variable in root height, at least in some human groups. Short root height for the maxillary central incisor has been noted on several occasions (Barker, 1973; Ketcham, 1927, 1929; Kraus et al, 1969); in some human groups - the Bantu and Australian Aborigines, the Norwegian Lapps and the people of Calvinia and Namaqualand, the Eskimos and American Indians, and in the people of Jarmo, Iraq - the maxillary central incisor root has been described as sometimes appearing shorter than would be expected from crown size (Abrahams, 1946-47; Campbell, 1925; Dahlberg, 1960; Hrdlicka, 1910; Pedersen, 1949; Shaw, 1931). For example, in the East Greenland Eskimos some $I^{\underline{1}}$ sockets were extremely small, measuring only 6 to 7 mm in height, and $I^{\underline{1}}$ roots of similar dimensions have been noted by Kovacs (1971). Selmer-Olsen (1949) has proposed that a relatively short $I^{\underline{1}}$ root should be regarded as a characteristic of the Norwegian Lapps.

As characterizing roots as short, or long, involves comparing the observed root height with what would be expected from crown size, unusually short or long roots are more fruitfully examined in the context of relative root height.

ii) Relative root height

Consideration of root height relative to crown height

or total tooth height has an advantage over examination of root height alone because it allows more meaningful comparison between teeth of different species and between teeth of different type. Kovacs (1971) has suggested the use of the following relative root height index - (root height/total tooth height) x 100 - and in a preliminary investigation comparing ?canines and M_T in some species, found that man showed greater similarity in relative root height to a carnivore (lion) than to gorilla and chimpanzee.

A relative root height index has also been used by authors interested in short-rooted maxillary central incisors. In a Swedish sample, Lind (1972) considered that some $I^{\underline{1}}$ roots were so short that they were anomalous. For this condition, he proposed the name 'short root anomaly' and outlined its characteristic features : the relative root height (root height/crown height) is less than or equal to 1.1; both $I^{\underline{1}}$s are affected almost symetrically; the roots often present a plump onion shape; and if other teeth are involved they are usually canines and premolars. In this sample, short-rooted $I^{\underline{1}}$s were often associated with external root resorption of the maxillary anterior dentition, and so two groups of affected individuals formed the basis of the study in conjunction with a control group (C-group) of individuals with normal-sized $I^{\underline{1}}$ roots : one in which short-rooted $I^{\underline{1}s}$ were associated with root resorption (R-group), and one in which they were not (S-group).

In the C-group, the mean value of relative root height was 1.6 (Lind, 1972), and in another study (Jakobsson &

Lind, 1973), the mean value of relative root height for all $I\frac{1}{-}$s was 1.6. This mean value is in keeping with the observation that $I\frac{1}{-}$ root height is usually about one and a half times crown height (Black, 1902; Diamond, 1952). In both the S-group and the R-group, the mean value of relative root height was 1.1 and according to Lind (1972), the difference in relative root height between the C-group and the R- and S-groups was not contributed to by crown height. On the contrary, Brook and Holt (1978) found that both crown height and root height were significantly shorter in individuals in which relative root height was 1.1 or less, though the difference in root height was much greater than that in crown height. The value of relative root height of 1.1 has been used for assessing an $I\frac{1}{-}$ root as short (Brook & Holt, 1978; Jakobsson & Lind, 1973; Lind, 1972), though Ando *et al* (1967) assessed an $I\frac{1}{-}$ root as short if its height was less than or equal to crown height.

Using these criteria, the incidence of short-rooted $I\frac{1}{-}$ was 2.4% in a Swedish sample (Jakobsson & Lind, 1973), 2.7% in a British Sample (Brook & Holt, 1978) and 10% in a Japanese sample (Ando *et al*, 1967). Brook & Holt (1978) have commented that the higher incidence in the Japanese sample may have partly resulted from the different methodology employed.

In one study, no statistically significant difference was found between the male and female values of relative root height for all $I\frac{1}{-}$s (Jakobbson & Lind, 1973). When individuals with an $I\frac{1}{-}$ relative root height of 1.1 or less

were examined, a sex difference was apparent; the male:female ratios being 1:2.6 and 1:2.7 in the Swedish samples (Jakobsson & Lind, 1973; Lind, 1972), 1:1.5 in the British (Brook & Holt, 1978) and 1:2.3 in the Japanese (Ando *et al*, 1967). Where tested, the sex difference was statistically significan (Jakobbson & Lind, 1973). In the Norwegian Lapps, Selmer-Olsen (1949) observed that a relatively large number of femal exhibited short $\underline{1}$ roots.

Opinion varies as to whether or not short-rooted $\underline{1}$s represent an anomaly. Lind (1972) and Jakobsson and Lind (1973) support this idea, and the former suggests that 'short root anomaly' is a constitutional anomaly of genetic origin - where he was able to examine the parents and siblings of affected individuals he established a familial occurrence in most cases. In another study, the hereditary nature of short-rooted $\underline{1}$s was established in a family where the father and two daughters were affected (Kovacs, 1971). Brook & Holt (1978) refute the idea of a distinct anomaly; in their opinion, short-rooted $\underline{1}$s represent one extreme of the continuous distribution of crown height:root height ratios. Moreover, they observed no characteristic root form in short-rooted $\underline{1}$s as Lind (1972) had done. Ando *et al*(1967) sought an explanation for short-rooted $\underline{1}$s in physiological factors, and investigated the possibility of an association between hypopituitarism and short roots, but their results were inconclusive. However, in their opinion there was evidence which supported the idea that short roots might result from the $\underline{1}$ crowns being subjected to unusually high occlusal load during the period of root formation. The presence of short-rooted $\underline{1}$s has been noted to be sometime

associated with the presence of certain abnormalities: crowding of the teeth (Jakobsson & Lind, 1973); root resorption and frontal crossbite (Lind, 1972); and an association with hypodontia was found to be statistically significant (Brook & Holt, 1978). Lind (1972) has suggested that an association with frontal crossbite might indicate a premaxillary growth insufficiency in such individuals.

Shortness of the roots in teeth other than $I^{\underline{1}}$ has been noted, particularly in mandibular canines and premolars, and especially in $P_{\overline{4}}$ (Ando et al, 1967; Campbell, 1925; Ketcham, 1927; Kraus et al, 1969; Lind, 1972; Nelson, 1938; Selmer-Olsen, 1949; Tratman, 1950). Brook & Holt (1978) investigate the association between short-rooted $I^{\underline{1}}$ and short-rooted $I^{\underline{2}}$, $I_{\overline{1}}$ and $M_{\overline{1}}$, and found that, in individuals with short-rooted $I^{\underline{1}}$s, the mean values of $I^{\underline{2}}$ crown height and root height were significantly less ($P < 0.001$) than in individuals with normal-rooted $I^{\underline{1}}$s.

Unusually long roots to certain teeth have also been commented upon (Barker, 1973; Brabant et al, 1961; Kraus et al, 1969; Shaw, 1931). Jakobsson and Lind (1973) investigated the incidence of long-rooted $I^{\underline{1}}$ in their Swedish sample an $I^{\underline{1}}$ was assessed as long-rooted if the value of relative root height was greater than or equal to 2.2. The incidence was found to be 2.3% - a similar incidence to the presence of short-rooted $I^{\underline{1}}$ in the same sample - and a statistically significant sex difference was demonstrated (male:female ratio 5:1). They noted an apparent association between long-rooted $I^{\underline{1}}$ and general long-rootedness of the teeth. In case reports from dental practice, several long-rooted

teeth have been extracted from the same patient (Barker, 1973; Roberts, 1936).

iii) Correlational studies on root dimensions

Studies have been conducted on the degree of relationship between the root heights of different teeth in the same jaw. In the maxillary dentition of the Norwegian Lapps (Selmer-Olsen, 1949), the correlation between the root height of a tooth and that of its neighbours (Table 4) is generally quite high, tending to be higher within tooth groups than between tooth groups. The root height correlation between adjacent teeth in the mandibular dentition are generally higher than those between corresponding pairs in the maxilla, though Selmer-Olsen (1949) notes that the difference is significant in only a few cases. The correlation coefficients reported by Garn et al (1978b) for root height between adjacent teeth from the $C_{\bar{1}}$ to $M_{\bar{2}}$ (Table 4) are very similar to those reported by Selmer-Olsen. In both jaws, the highest correlations are found within the anterior dentition, whilst the lowest is between the second premolar and first molar (Garn et al, 1978b; Selmer-Olsen, 1949).

The root height of $M^{\bar{1}}$ was compared with the root height of other maxillary teeth in the Norwegian Lapps (Selmer-Olsen, 1949), and the strength of relationship was found to diminish with increasingly distant teeth (Table 5). In the Norwegian Lapps, this tendency was not apparent when the root height of $M_{\bar{1}}$ was compared with the root height of other mandibular teeth (Table 5). For the $C_{\bar{1}}$ to $M_{\bar{2}}$, Garn et al (1978b) correlated the root height of each tooth with that of each

Table 4 : Correlation coefficients for root height between adjacent teeth in modern man

	Mandibular				Maxillary	
	Garn et al 1978b		Selmer-Olsen 1949		Selmer-Olsen 1949	
	r	N	r	N	r	N
I1-I2	-	-	0.78	365	0.71	215
I2-C	-	-	0.71	380	0.68	251
C-P3	0.65	122	0.65	332	0.54	276
P3-P4	0.67	122	0.64	230	0.67	240
P4-M1	0.56	122	0.54	230	0.39	106
M1-M2	0.62	122	0.61	175	0.62	88
M2-M3	-	-	0.64	122	0.56	113

Table 5 : Correlation coefficients for root height between certain teeth in modern man

		I1	C	P3	P4	M1	M2	M3
Mandibular								
(Garn et al, 1978b)	$C_{\overline{1}}$	-	-	0.65	0.44	0.44	0.35	-
	$P_{\overline{3}}$	-	-	-	0.67	0.51	0.48	-
	$P_{\overline{4}}$	-	-	-	-	0.56	0.57	-
	$M_{\overline{1}}$	-	-	-	-	-	0.62	-
(Selmer-Olsen, 1949)	$M_{\overline{1}}$	0.56	0.58	-	0.54	-	0.61	0.39
Maxillary								
(Selmer-Olsen, 1949)	M^{1}	0.26	0.34	-	0.39	-	0.62	0.56

other tooth. On the basis that the average correlation coefficient for adjacent teeth was 0.63, for teeth once removed was 0.51, and for teeth twice removed was 0.46, Garn et al (1978b) proposed that "these findings are consistent with a distance 'field' of decreasing intensity affecting the roots of adjacent teeth".

Selmer-Olsen (1949) has suggested that there may be an inverse relationship between root height and root bifurcation in maxillary premolars - that single roots tend to be longer than bifurcated ones and that, as root bifurcation becomes more pronounced, root height tends to become shorter. Turner (1981) found no evidence to support this relationship insofar as there was no relationship ($r = -0.13$) between buccal root height and bifurcation height in two-rooted P^3s.

Some studies have attempted to elucidate the relationship between root height and crown dimensions. In a preliminary study on certain mandibular teeth (Garn et al, 1978a), root height was proposed to be systematically and positively correlated with both crown mesiodistal diameter and crown buccolingual diameter, though it was noted that the correlations were of a low order of magnitude. Using a larger sample in a later study (Garn et al, 1978c), it was proposed that these results were confirmed. However, the correlation coefficients obtained (Table 6) - the highest being of the order of 0.2 - do not justify the following conclusion:

> "the consistently positive pooled-sex crown size/root length correlations do reveal the existence of a novel dimensional 'field' affecting each tooth

Table 6 : Corrleation coefficients between root height and crown dimensions in certain teeth of modern man

	C	P3	P4	M1	M2	Reference
Mandibular						
Crown mesiodistal	0.20	0.14	0.14	0.11	0.05	Garn et al, 1978c
Crown buccolingual	0.13	0.24	0.07	0.05	0.06	Garn et al, 1978c
Crown height	0.57	0.18	0.16	0.24	0.20	Selmer-Olsen, 1949
Maxillary						
Crown height	0.32	0.26	0.09	0.11	0.07	Selmer-Olsen, 1949

> as a whole. It is impressive that the crowns of permanent teeth that begin to form by the second trimester of prenatal life and that complete their size-attainment in the second to fifth year of postnatal life thus 'anticipate' the length of still-to-be completed roots by 10 years or more." (Garn et al, 1978c)

Rather, the values of the correlation coefficients indicate the absence of a relationship between root height and either of the crown dimensions. In the same way, the following conclusions are unjustifiable:

> "mesiodistal crown-size measurements apparently show higher correlation with root length (r = 0.13) than do the analagous buccolingual crown size values (r = 0.11)." (Garn et al,1978c)

In the Norwegian Lapps, there is evidence of a relationship between root height and crown height for the mandibular canine (Table 6), but not for the post-canine dentition (Selmer-Olsen, 1949).

Facial shortening and root height

In response to claims that facial shortening and the reduction of tooth size have been interrelated during the course of human evolution, several studies have investigated the relationship between these two features.

In an experimental study, facial shortening was produced in rats by surgical excision of the nasal septum, which resulted in a high degree of shortening of the nasal bones and palate, and also of the frontals and parietals, but left the mandible almost unaffected (Riesenfeld, 1970). While there was no associated significant reduction in molar crown size, with the exception of the crown buccolingual diameter of $M^{\frac{1}{1}}$, there was in molar root height. The reduction

of root height was greater in the maxillary molars - the region more affected by the operation - than in the mandibular molars, and increased distally from the first to the third molar - a sequence which Riesenfeld (1970) noted parallels the order of crown size reduction during human evolution. The indications of a relationship between facial size and root height prompted further investigation (Riesenfeld, 1970); this time on a sample of dogs - English bulldogs and German shepherd dogs. Dogs were chosen as they offer a ready-made opportunity for investigating this relationship because, as a species, they exhibit wide variation in muzzle length. In the short-faced dogs, total tooth height was found to be much shorter than in long-faced dogs, and in addition, examination of the crown height: root height ratios showed that the maxillary roots were relatively shorter than in the long-faced dogs. When short-faced dogs are compared with long-faced dogs, the maxilla is much more reduced than the mandible, and so the difference in root reduction between the maxillary and mandibular teeth was considered to parallel the findings in rats (Riesenfeld, 1970).

A later study on a larger sample of dogs (Riesenfeld & Siegel, 1970) investigated the relationship between relative root height (root height x 100/root height + crown height) and palatal index (palatal breadth x 100/palatal length). The palatal index was used, rather than palatal dimensions, as it was considered to reflect facial shortening more accurately. A relationship between facial proportions and relative root height was established, but only for some teeth (Table 7). In the maxilla, two areas of significant

Table 7 : Correlation coefficients between relative root height and palatal index in a sample of dogs (Riesenfeld & Siegel, 1970)

	Mandibular		Maxillary	
	r	N	r	N
I1	-0.16	43	-0.48**	48
I2	-0.49**	47	-0.64**	51
I3	-0.69**	45	-0.65**	55
C	-0.27*	59	-0.53**	59
P1	-0.45**	43	-0.18	54
P2	-0.05	54	-0.04	50
P3	-0.15	59	-0.25	59
P4	-0.32*	59	-0.53**	59
M1	-0.60**	60	-0.59**	60
M2	+0.04	55	-0.15	54
M3	-0.07	30	-	-

* $P \leqslant 0.05$

** $P \leqslant 0.01$

Table 8 : Correlation coefficients between root height and jaw dimensions in Papio anubis (Siegel, 1972)

	Palatal length			Mandibular length		Mandibular depth	
	r	N		r	N	r	N
$I\frac{1}{-}$	0.31*	36	$I\frac{-}{1}$	0.39**	37	0.36*	37
$I\frac{2}{-}$	0.38*	36	$I\frac{-}{2}$	0.44**	39	0.49**	39
$C\frac{1}{-}$	0.73**	33	$C\frac{-}{1}$	0.81**	34	0.82**	34
$P\frac{3}{-}$	0.45**	36	$P\frac{-}{3}$	0.89**	34	0.83**	34
$P\frac{4}{-}$	0.36*	37	$P\frac{-}{4}$	0.38**	39	0.43**	39
$M\frac{1}{-}$	0.46**	32	$M\frac{-}{1}$	0.35*	36	0.37*	35
$M\frac{2}{-}$	0.35*	24	$M\frac{-}{2}$	0.57**	40	0.58**	40
$M\frac{3}{-}$	0.35*	33	$M\frac{-}{3}$	0.63**	33	0.71**	33

* $P \leqslant 0.05$

** $P \leqslant 0.01$

correlation were found; in the region of the premaxillary suture ($I\frac{1}{1}I\frac{2}{2}C\frac{1}{1}$) and in the region of the maxillary-palatine suture ($P\frac{4}{4}M\frac{1}{1}$). Riesenfeld and Siegel (1970) suggest that, as these regions are areas of active maxillary growth, they are the regions most likely to be affected by facial shortening. Two regions of significant correlation were also found in the mandible; these corresponded to the maxillary regions except that the anterior cluster was shifted one tooth distally. Thus, this study on dogs indicated (Riesenfeld & Siegel, 1970) that, as in rats, there is a relationship between shortening of the face and shortening of the tooth roots - at least for some teeth.

The investigation of the relationship between facial dimensions and tooth size was extended to a sample of Papio anubis (Siegel, 1971, 1972), baboons being a primate group which exhibit marked facial protrusion. Having identified two maxillary clusters of significant correlation - each being in an area of growth - in dogs, the particular interest of this study was the investigation of the relationship between facial growth and root growth. In the maxilla, there were found to be two areas of high correlation between palatal length and root height (Table 8) which were considered to be comparable to the two clusters documented in dogs. According to Seigel (1972), the higher correlations between root height and palatal length found for teeth located in the regions of the palatal sutures reflect the influence of these areas of active growth - through which palatal size is achieved - on root growth - through which root height is achieved. In the mandible, the patterns of high correlation were not completely comparable in baboons and dogs. In both,

an anterior cluster of significant correlations was identifiable, but while in dogs only M_1 of the molars showed any relationship with facial protrusion, in Papio anubis this was found in the distal molars. This pattern of correlation between root height and mandibular dimensions was thought by Siegel (1972) to reflect increasing proximity to the ramus - the most active area of mandibular growth. For all mandibular teeth, the correlation coefficients computed between root height and mandibular length were very similar to those computed between root height and mandibular depth; partial correlational analysis revealed that, of the two mandibular dimensions, mandibular depth had the stronger relationship with root height. Siegel (1972) suggested that a factor which may contribute to the relationship between mandibular depth and root height is the added support which increased mandibular depth gives to the molars as they come into occlusion. In connection with this, a study on cercopithecoid primates (Ward, 1978) has shown that the height of the mandibular alveolar process is not solely a function of mandibular root height. The compatibility of the results from the baboon sample with those from the rat and dog samples led Siegel (1972) to suggest a general mammalion trend in the relationship between facial protrusion and root height:

> "within a given population there exists a biomechanical mechanism which transmits changes in ontogenetic growth rates of the facial skeleton to the roots of the teeth." (Siegel, 1972).

Published values of root height and facial dimensions

for modern man have been suggested to corroborate the relationship between facial shortening and root reduction (Riesenfeld, 1970; Siegel, 1972). In human groups such as the Bantu, where palatal length is longer than in other human groups such as the Eskimo, root height tends to be greater. Investigation of the relationship between facial dimensions and root height in modern man is very limited. In an American sample (Garn et al, 1980), no relationship was found between mandibular root height ($C_{\bar{1}}$ to $M_{\bar{2}}$) and facial depth (nasion-articulare) or facial length (nasion-gnathion). However, correlation coefficients of the order of 0.2 to 0.3 computed between mandibular root height and jaw length (articulare-gnathion), taken together with the results of previous studies (Garn et al, 1978a b c), were considered to provide sufficient evidence to support the evidence of "a low order, general size factor involving crowns, roots and faces" (Garn et al, 1980). In the Norwegian Lapps, correlation coefficients were computed between upper facial height and the root height of $I^{\underline{1}}$ (0.55), $C^{\underline{1}}$ (0.45) and $M^{\underline{1}}$ (0.28), and these results were suggested to show a link between the teeth and the proportions of the face (Selmer-Olsen, 1949). Some attention has been given to the relationship between root height and facial size in the Krapina neanderthal remains, though no results were reported (Rossman, 1971).

According to Siegel (1972), the only theory of phylogenetic tooth size reduction which can be supported by experimental work is that which considers facial shortening as the cause. He has also suggested that shortening of the roots and tooth agenesis are, respectively,

partial and extreme expressions of tooth reduction.

iv) Root surface area and volume studies

Interest in root surface area and root volume has arisen mainly within the field of dentistry; even so the number of studies concerning these topics is very limited.

Root surface area

Early attempts to quantify root surface area considered the roots as geometric shapes and so root surface area was calculated by means of mathematical formulae (Morelli, 1920, cited by Jepsen, 1963). In order to overcome the obvious limitations of such an approach, more accurate methods have been devised. A commonly used technique requires the making of a root 'pattern'; a suitable substance is applied to the root which, when removed, forms a two-dimensional root 'pattern' which can be easily measured (Brown, 1950; Crabb et al, 1974; Jepsen, 1963; Kovacs & Kaan, 1966; Kovacs, 1971; Muller, 1959; Naumov, 1965; Watt et al, 1958). In response to the requirement of more detailed data for the stress analysis of teeth, Nicholls et al (1974) devised a more sophisticated approach to the determination of root surface area. This involved sectioning a model of the tooth, and then, using a digitizer, recording the circumference of each section as a series of co-ordinates. The co-ordinates of the sections can be used to compute root surface area and, in addition, they can provide three-dimensional information about root shape. Despeignes (1979) has proposed a method for measuring root surface area based on galvanizing the root with a layer of silver, and then measuring its electrical capacity.

With the aim of providing a more accurate estimate of root surface area for *in situ* teeth than is given by the mean values determined for extracted teeth, Jepsen (1963) investigated the relationship between root surface area and the area of the mesiodistal root section as it appears on a lateral radiograph. The regression line between these two variables was computed for each tooth except third molars, and so provides a means of estimating the root surface area of an *in situ* tooth from the area of its radiographic root section. Although the method was not tested clinically, Jepsen considered that root surface area could be estimated with an accuracy of $\pm$ 10-15%.

The mean values of root surface area determined by different authors are very similar (Table 9), with the exception of the values reported by Tylman & Tylman (1960). However, Tylman & Tylman did state that their values were to be used only for comparison between themselves. As noted by Jepsen (1963), the first molar of each jaw shows the largest surface area, whilst $I_{\overline{1}}$ and $I^{\overline{2}}$ show the smallest.

The only study which has measured root surface area separately for each sex is that of Crabb *et al* (1974), and for the maxillary canine only. For this tooth, the male and female mean values were statistically significantly different ($P < 0.01$).

Study has been made of the reduced root surface area available for fibre attachment which results from alveolar bone recession (Brown, 1950). Brown's results are of interest in that they indicate a relationship between root shape and

Table 9 : Published mean values of root surface area (mm^2) in modern man

Reference	I1	I2	C	P3	P4	M1	M2	M3
Mandibular								
Watt et al, 1958	162	175	272	197	204	450	400	373
Jepsen, 1963	154	168	268	180	207	431	426	-
Naumov, 1965	143	173	223	206	227	383	346	-
Kovacs & Kaan, 1966	-	-	-	162	171	390	278	254
Tylman & Tylman, 1960	103	124	159	130	135	352	282	190
Maxillary								
Watt et al, 1958	205	177	267	220	217	455	417	305
Jepsen, 1963	204	179	273	234	220	433	431	-
Naumov, 1965	202	170	295	244	241	522	410	-
Kovacs & Kaan, 1966	-	-	-	240	220	370	350	287
Tylman & Tylman, 1960	139	112	204	149	140	335	272	197
Brown, 1950	192	-	-	-	-	-	-	-
Crabb et al, 1974 male	-	-	263	-	-	-	-	-
female	-	-	236	-	-	-	-	-

the degree to which effective surface area is reduced by alveolar recession. In $I\frac{1}{1}$ roots which had an even, sharp taper from the cemento-enamel junction, there was more rapid reduction in the surface area available for fibre attachment than in $I\frac{1}{1}$ roots which had relatively parallel sides in the cervical region. For example, depending on the shape of the root, after 4 mm of alveolar bone recession, between 39% and 60% of the original area would remain available for fibre attachment.

In spite of the fact that root surface area is considered to play an important role in the transmission of forces during mastication (Kovacs, 1971, 1979), there have been few attempts to elucidate the relationship between crown surface area and root surface area. The index root surface areax100/crown surface area has been calculated for the $C\frac{-}{1}$ and $M\frac{-}{1}$ of a few species (Kovacs, 1971). For the $C\frac{-}{1}$, the value recorded for man (154) was very similar to that recorded for lion (156), while chimpanzee (217) and particularly gorilla (286) showed higher values. The values of the index for $M\frac{-}{1}$ were considerably smaller in man (128), chimpanzee (158), and gorilla (166) than in horse (301). Kovacs (1971) has also suggested the use of a different index to illustrate the functional relationship between the crown and root, this being root surface area x100/crown surface area+crown height^2, though its significance is lost on this author. Kovacs and Kaan (1966) have computed the index root surface area/occlusal area for the postcanine dentition of a human sample. In both jaws, the values of this index were higher in the premolars than in the molars. With the exception of the first molars, the

value of the index for a maxillary tooth was higher than that of its mandibular counterpart. The relationship between root surface area and occlusal area, and between root surface area and functioning occlusal area have been investigated in a few animal species by Kloehn (1938). He proposed that there is a uniform ratio between root surface area and functioning occlusal surface which is independent of the form and function of the teeth. It is difficult to comment on the validity or significance of this observation as no mention was made of how the area measurements were derived, nor of the number of specimens examined.

Root volume

Very little work has been done on the volume of tooth roots. Published values (Table 10) are available for the postcanine dentition of American Whites and Negroes (Moss et al, 1967) and for a sample of Germans (Muller, 1963). In both studies, root volume was measured by the technique of liquid displacement. While stating that the obtained values for root volume were rough approximations at best, the results of Moss et al (1967) indicated greater mean values of root volume in the American Negroes than in the American Whites, though the differences were statistically significant ($P < 0.01$) only for the maxillary premolars, M^3 and M_2. Moss et al (1967) noted that the greater root volume of these teeth did not result from larger root size, but rather from greater root robusticity in the American Negro.

Table 10 : Published values (cm^3) of root volume, and root volume expressed as a percentage of total tooth volume, in modern man

		I1	I2	C	P3	P4	M1	M2	M3	Reference
Mandibular										
American Whites	$\bar{X}$	-	-	-	0.28	0.31	0.68	0.61	0.60	Moss et al, 1967
	%	-	-	-	55	51	52	57	55	" "
American Negroes	$\bar{X}$	-	-	-	0.34	0.33	0.77	0.86	0.63	" "
	%	-	-	-	52	48	60	64	59	" "
Germans	min	0.15	0.13	0.24	0.20	0.20	0.59	0.49	0.20	Muller, 1963
	max	0.20	0.19	0.40	0.25	0.26	0.79	0.72	0.47	" "
Maxillary										
American Whites	$\bar{X}$	-	-	-	0.31	0.31	0.76	0.69	0.53	Moss et al, 1967
	%	-	-	-	50	52	60	(58)	56	" "
American Negroes	$\bar{X}$	-	-	-	0.37	0.43	0.72	0.81	0.74	" "
	%	-	-	-	50	46	55	(57)	60	" "
Germans	min	0.18	0.16	0.30	0.21	0.21	0.61	0.52	0.21	Muller, 1963
	max	0.34	0.26	0.50	0.28	0.28	1.11	1.00	0.33	" "

Part I

Chapter 3 : Studies on the variation of root form and number

A: Root reduction in multi-rooted teeth

i) Root reduction in premolar roots

ii) Root reduction in molar roots

B: Root increase in incisors, canines and molars

i) Root increase arising through apical bifurcation

ii) Root increase arising through accessory roots

Chapter 3 : Studies on the variation of root form and number

While variation in root form and number is commonly encountered in the premolars of the primate dentition, with certain exceptions the roots of incisors, canines and molars depart little from a basic pattern within this Order. Canines, and particularly incisors, are almost always single-rooted teeth. The molars usually exhibit the generalized eutherian pattern; one lingual and two buccal roots for maxillary molars, and one mesial and one distal root for mandibular molars (Butler, 1941; Clark, 1971; Gregory, 1920-21).

However, at least as far as the modern human dentition is concerned, variation in form and number is documented for all roots. The following survey will approach variation in root form and number according to whether the observed morphology indicates a tendency towards root reduction (section A) or root increase (section B).

A : Root reduction in multi-rooted teeth

i) Root reduction in premolar roots

In most extant primates, with the notable exception of Homo sapiens, mandibular premolars are usually two-rooted and maxillary premolars are usually three-rooted (Colyer, 1936; Duckworth, 1923; James, 1960; Owen, 1840-45; Peyer, 1968; Scott & Symons, 1974; Senyurek, 1953; Tomes, 1923). However, exceptions to this generalisation do occur; particularly in some prosimians and New World monkeys, two-rooted or even single-rooted maxillary premolars have been documented, as have single-rooted mandibular premolars (Colyer, 1936; Duckworth, 1923; James, 1960; Owen, 1840-45; Senyurek, 1953; Tomes, 1923). Such observations seem to indicate that when there is reduction in root number it is found anteriorly within the premolars e.g. in many prosimians, $P^{\underline{3}}$ and $P^{\underline{4}}$ have three roots while $P^{\underline{2}}$ has two roots and $P_{\overline{3}}$ and $P_{\overline{4}}$ have two roots while $P_{\overline{2}}$ has one root (Senyurek, 1953). This trend is also observable in some fossil prosimian genera (Quintet, 1966). In contrast to the other pongids, $P^{\underline{4}}$ is often two-rooted in Pan and the roots of the mandibular premolars may exhibit some degree of root fusion (Colyer, 1936; Duckworth, 1923; James, 1960; Tomes, 1923). In a population of Hylobates lar, $P_{\overline{3}}$ was observed to be supported by three roots - the additional root being distolingual - in about 44% of the sample (Frisch, 1963, 1973).

Mandibular premolar roots in the Hominidae

In some early fossil hominids, the $P_{\overline{3}}$ roots are reminiscent of pongids and Miocene hominoids (Ward, 1979).

The P_3 has a mesiobuccal root, which tends to be oval in cross-section and orientated obliquely so that the buccal part is mesially in advance of the lingual part, and a distal root, which is mesiodistally compressed and orientated transversely (Johanson & White, 1979; Johanson et al, 1978; White, 1977). This root form is mentioned in the description of Australopithecus afarensis, and has been described for L.H.4, A.L. 333w-60, KNM-ER 818, KNM-ER 1803 (Day et al, 1976; Johanson & White, 1979; Johanson et al, 1978; Leakey & Walker, 1973; White, 1977). It may also be present in TM 1517; when first described, the P_3 root cross-section was described as "somewhat ternate, suggesting that the root deeper in the jaw may divide into a smaller anterior root and possibly two posterior roots"(Broom & Schepers, 1946). In the Hadar specimens, P_4 usually has two roots which are mesial and distal, and so too do L.H.4 and TM 1517 (Broom & Schepers, 1946; Ward, 1979; Ward et al, 1982; White, 1977).

In two Hadar specimens the P_3 is three-rooted, and so too is the P_3 L.H. 24 in which the roots are mesiobuccal, distobuccal and distolingual (Ward, 1979; White, 1980).

In his study of the South African australopithecine dentition, Robinson (1956) noted that P_3 may have the following root form:

> "Where two separate roots are present, there is a mesial one and a distal one, the latter being broader buccolingually than the former. The greater width of the distal root is associated with the greater lingualuard extension of the distolingual portion of the crown. Both roots have a longitudinal depression on both mesial and distal faces." (Robinson, 1956).

This P_3 root form was observed in some Swartkrans specimens, and was suggested to be also present in some Sterkfontein P_3s (Robinson, 1956; Sperber, 1974). The P_3 of KNM-ER 1806 has roots of similar form, being described as:

> "in the form of two dumbell-shaped plates separated by a bony septum and parallel to one another, but the distal plate is displaced lingually. The plates also differ in shape, the buccal end of the mesial plate and the lingual end of the distal plate are more swollen than the opposite ends". (Day et al, 1976)

In the P_3 SK 72 the distal root exhibits apical bifurcation (Sperber, 1974). From the illustration provided, it seems likely that mesial and distal roots are present in the Omo P_3 L18-33 from Member D (Coppens, 1970). The P_4 of KNM-ER 1806 also has mesial and distal roots of which the distal is displaced lingually (Day et al, 1976), and so too do the P_4s SK 7, SK 876 and TM 1523 (Robinson, 1956; Sperber, 1974). Similar displacement between the roots is seen in SK 88, though Sperber (1974) noted that three roots are present in this specimen. In TM 1523, the lingual portion of the distal root is more strongly developed than the corresponding part of the mesial root, while the converse applies for the buccal parts of the roots (Robinson, 1956).

Two-rooted P_4s have been described for other fossil hominid specimens. Of the four in situ Swartkrans P_4s for which root form could be assessed, all appeared to have two roots (Robinson, 1956). Plate-like mesial and distal roots have been described for the P_4s of several Koobi Fora hominids - KNM-ER 725, 726, 727, 729 (Leakey et al, 1972), KNM-ER 733, 810

(Leakey & Walker, 1973) and KNM-ER 1468 (Day et al, 1976). The P_4 root cross-section of KNM-ER 1811 has been described as "bifid with two waisted plates separated by a bony septum" (Day et al, 1976). Both O.H.51 and Sangiran 9 have mesial and distal roots supporting the P_4 (Jacob, 1973; Rightmire, 1980; Von Koenigswald, 1968, 1969).

In contrast to the P_3 root forms so far described, the Kromdraai P_3, TM 1600, has mesiobuccal and distolingual roots (Sperber, 1974). The same root form is present in Sts 7 and probably in Sts 51, and also in SK 72 though distobuccally the bifurcation is displaced apically for a short distance (Robinson, 1956). Some Hadar P_3s (Ward, et al, 1982) may exhibit this root form.

The tendency exhibited by SK 72 - for the distobuccal bifurcation to be displaced apically - is expressed completely in other hominid P_3s - those in which the distobuccal bifurcation is absent. The root form of such specimens is known as Tomes' root as it was first described by Tomes (1923) in connection with its occurrence in the P_3 of modern man. Tomes' root is found in some Swartkrans P_3 specimens (Robinson 1952, 1956), where it has been described thus:

> "Where two partially fused roots occur - that is Tome's (sic) root form - a well-developed cleft is present on the mesiolingual face of the root system. This cleft passes diagonally inward toward the distobuccal face of the root, but there is usually no indication of a cleft or groove in that position. The mesiolingual cleft is narrow near the enamel line - which it does not actually reach -

and widens as it passes toward the apex." (Robinson, 1956).

In the P_3 SK 30, Tomes' root is present and the distobuccal root surface is marked by a longitudinal groove (Robinson, 1956). In isolated Swartkrans P_3s the cervical line was noted to dip inferiorly above the mesiolingual cleft, and this feature has been used to indicate the presence of Tomes' root in six *in situ* Swartkrans P_3s (Broom & Robinson, 1952; Robinson, 1952). Tomes' root is also probably present in the *in situ* P_3s of Sts 36 and Sts 526 (Robinson, 1952, 1956). It would seem that, either from the descriptions or from the illustrations provided, that Tomes' root is found in the P_3 of some Hadar specimens including A.L. 288-1, L.H.14, KNM-ER 812, O.H.22, the Kedung Brubrus mandible and the isolated Trinil specimen, Sangiran 8, *Atlanthropus*, *Sinanthropus* specimens no's 82 and 85 and some Krapina specimens (Arambourg & Hoffstetter, 1963; Day *et al*, 1976; Dubois, 1924; Jacob, 1973; Johanson *et al*, 1982; Kallay, 1963; Rightmire, 1980; Von Koenigswald, 1968, 1969; Ward *et al*, 1982; Weidenreich, 1937, 1945; White, 1980). In comparison to the well-developed mesiolingual cleft found in some Swartkrans P_3s, the cleft may be less well-developed in some of these hominids so that the partial division between the 'roots' is less pronounced.

Just as the P_3 of some hominids shows the tendency towards root reduction, so too may the P_4. Radiographically, the P_4 of Hadar specimens A.L.288-1 and A.L.400-1a exhibit root bifurcation only in the apical region (Johanson *et al*, 1982; Ward *et al*, 1982). The Omo P_4 L75i-1255 has a root

which has been described as "dédoublée lingualement" (Coppens, 1973b). The radiograph of Atlanthropus III shows bifurcation into mesial and distal roots for the P_4, but these are separate for only about half the root height (Arambourg & Hoffstetter, 1963). A similar P_4 root form is present in the 1939 mandible of Pithecanthropus dubius (Weidenreich, 1945) and the Rabat mandible (Howell, 1960).

To return to P_3, it can be appreciated that when Tomes' root is very weakly expressed, the root is effectively single and very comparable to the usual P_3 root form of modern man. The following hominid specimens have single-rooted P_3s: SK 18A, an isolated Sterkfontein specimen, the Pithecanthropus modjokertensis mandible from Sangiran, the Sidi Abderrahman mandible, Sinanthropus no's. 21 and 23, and some Krapina specimens (Arambourg & Biberson, 1956; Broom et al, 1952; Kallay, 1963; Sperber, 1974; Von Koenigswald, 1968; Weidenreich, 1937). In an outline of the genus Pithecanthropus, the mandibular premolars were described as having one or two roots (Jacob, 1975).

Von Koenigswald (1968, 1969) has described the P_4s of the Pithecanthropus modjokertensis mandible and of the Meganthropus mandible from Sangiran as single-rooted. However, Robinson (1968) has disagreed with the observation of a single-rooted P_4 in the latter mandible; he suggests that a lingual root cleft is probably present on the P_4 thereby indicating partial bifurcation. He also noted that the left P_4 of the 1952 specimen is two-rooted. The only Sinanthropus

P_4 for which root form could be assessed was Sinanthropus no. 93, and this is effectively single-rooted showing two apices only in the most apical area in relation to a deep cleft on the mesial part of the lingual surface (Weidenreich, 1937). The isolated P_4 from Changyang appears to be single-rooted with a short cleft close to the apex (Chia, 1957).

The variation of P_3 root form in fossil hominids led Robinson (1952) to postulate a sequence of root reduction from two-rooted to single-rooted teeth. Starting with a hypothetical stage in which two separate roots were present, he envisaged that P_3 root reduction had taken place through the following stages: firstly, a single root showing a mesiolingual cleft and distobuccal groove; secondly, a single root having only a mesiolingual cleft/groove; and lastly, a single root with no grooves.

In modern human populations, the mandibular premolars are usually described as single-rooted (Barker et al, 1973; Duckworth, 1923; Scott & Symons, 1974; Sprinz, 1953); however, examination of published information reveals that there is variation in root form for these teeth.

The root of a human mandibular premolar may be single and conical, tapering to a single apex, or it may be marked by longitudinal root grooves which may lead to bifurcation (Goh , 1957). A groove of common occurrence is the mesiolingual groove - which has been referred to previously in connection with the presence of Tomes' root in hominid P_3s.

This is found on the mesial root surface and is positioned some one-third of the distance from the lingual to the buccal root border. A range of expression is encountered in its development: the groove may be superficial, or it may penetrate to varying degrees into the root along the mesiolingual-distobuccal axis - when it is better described as a cleft (De Jonge, 1961b; De Jonge-Cohen, 1919; Goh, 1957; Gher & Vernino, 1980). When a cleft is present this is equivalent to the presence of Tomes' root; the cleft becomes more pronounced apically and may lead to bifurcation into mesio-buccal and distolingual apices (De Jonge-Cohen, 1919; Diamond, 1952; Goh, 1957; Scott & Symons, 1974; Tomes, 1923) although De-Jonge (1961b) described them as mesiobuccal and distal. In some specimens, the mesiolingual groove or cleft is accompanied by a longitudinal groove on the distal or buccal root surface (Goh, 1957; Kraus et al, 1969). In cross-section, Tomes' root is C-shaped with the open part of the 'C' corresponding to the mesiolingual cleft. The pulp usually divides at some level within the root to form two canals in mesiobuccal and distolingual positions. In unusual specimens, Tomes' root may lead to bifurcation in the middle, or even cervical, third of root height so that two well-formed roots are present; examples of two-rooted human mandibular premolars have been reported (Barker, 1973; Brabant, et al, 1953; De la Parra, 1952; Pearlman, 1972; Shapira & Delivanis, 1982). Even more unusual is the presence of three roots in a human mandibular premolar, but examples have been documented (Armitage, 1971; Barker, 1973; Brabant et al, 1961; De Jonge, 1961b; De Jonge-Cohen, 1919; De la Parra, 1953; Shapira & Delivanis, 1982).

P_3 exhibits greater variation in root morphology than P_4

(Brabant et al, 1953; Sprinz, 1953). In Tratman's sample of Malays, 66% of P_4s, but only 33% of P_3s, showed a single, conical grooveless root (Goh, 1957). The mesiolingual groove was present in 32% of P_3s and 10% of P_4s, leading to apical bifurcation in 5% of P_3s and 1.5% of P_4s (Goh, 1957). Including bifurcations which stemmed from root grooves other than the mesiolingual groove, the overall incidence of bifurcated roots in this sample was 6.7% of P_3s and 1.5% of P_4s and these figures are in keeping with Tratman's observation that two-rooted premolars were rare in this sample, but contradict his statement that two roots were more common in P_4 than in P_3 (Goh, 1957; Tratman, 1950).

Mandibular premolar root form has been documented for other human groups, and in all more variation has been encountered in P_3 than in P_4. In the Pecos Pueblo Indians, Tomes' root was exhibited by 10% of P_3s and 4% of P_4s, and it was inferred that no examples of bifurcated roots were observed (Nelson, 1938). In the East Greenland Eskimo (Pedersen, 1949), all mandibular premolars were single-rooted except for one P_3 (1.4%) which exhibited Tomes' root. The frequency of root bifurcation in the Norwegian Lapps was 10% for P_3 and 2.2% for P_4 (Selmer-Olsen; 1949); for P_3, males exhibited a slightly higher frequency (12.5%) than the females (9.7%). In most of the specimens, the bifurcation was limited to the apical third of the root, but for 1.2% of P_3s and 0.2% of P_4s it extended into the middle third of root height. In a sample of British teeth, 84% of P_3s were single-rooted while 7% of P_4s had two roots (Taylor, 1899). No examples of Tomes' root were observed in the people of Calvinia and Namaqualand, but bifurcated roots were recorded for both P_3 and P_4 (Abrahams,

1946-47). In the Bantu (Shaw, 1931), a high frequency of Tomes' root has been documented for $P_{\bar{3}}$ (36.9%) and a very much lower frequency for $P_{\bar{4}}$ (8.4%). Campbell (1925) did not comment on Tomes' root in the mandibular premolars of the Australian Aborigine, but did note that occasionally there was "a tendency for the partial or complete formation of two roots".

Maxillary premolar roots in the Hominidae

In the description of Australopithecus afarensis, it was noted that $P^{\underline{3}}$ is sometimes three-rooted (Johanson & White, 1979; Johanson et al, 1978), and this root form is also found in the maxillary premolars of other fossil hominids. The Sterkfontein $P^{\underline{3}}$ - Sts 54 - has three roots, being recorded as the only specimen of thirteen A.africanus $P^{\underline{3}}$s from this site to exhibit this root form (Robinson, 1956). However, Sperber (1974) has noted two three-rooted $P^{\underline{3}}$s in this site sample. In a more recently described specimen - Stw 53 - which comes from Member 5 and has been referred to Homo, both $P^{\underline{3}}$ and $P^{\underline{4}}$ are three-rooted (Hughes & Tobias, 1977). The in situ $P^{\underline{3}}$ and $P^{\underline{4}}$ of TM 1517 and the $P^{\underline{4}}$ of the fragmentary right maxilla from Kromdraai have apparently three separate roots (Broom & Schepers, 1946; Robinson, 1956). Most, but not all, of the Swartkrans maxillary premolars are three-rooted: for $P^{\underline{3}}$ this root form was recorded for fifteen out of twenty specimens by Robinson (1956) and for eight out of fourteen by Sperber (1974); for $P^{\underline{4}}$, eight out of ten specimens have three roots (Robinson, 1956). In addition, three-rooted maxillary premolars have been recorded for the following hominid specimens: KNM-ER 405, KNM-ER 406, KNM-ER 732, KNM-ER

733, SK 80, O.H.5, Pithecanthropus IV (Leakey et al, 1971, 1972; Leakey & Walker, 1973; Robinson, 1953; Tobias, 1967; Von Koenigswald, 1969).

However, only in some of the Swartkrans maxillary premolars, e.g. the P^4 SK 65, are the three roots equally separate; in others, there is evidence of root fusion (Robinson, 1956). One type of root fusion is encountered in specimens such as the P^3 SK 24 and the P^4s SK 28 and SK 32 in which there is fusion between the mesiobuccal and lingual roots, so that only the apices of these two roots are distinct, while the distobuccal root is separate (Broom & Robinson, 1952; Robinson, 1956; Sperber, 1974). In maxillary premolars such as the P^3 SK 74c and the P^4s SK 39 and SK 11 another type of root fusion is encountered; the two buccal roots are fused for the greater part of their root height while the lingual root is distinct (Robinson, 1956; Sperber, 1974). This type of root fusion is also exhibited by the Laetoli specimens L.H.25, a P^3, and L.H.22, a P^4 (White, 1977, 1980).

Fusion between the two buccal roots renders the premolar effectively two-rooted. Both premolars of L.H.5 have two roots - one buccal and one lingual - and the buccal root of the P^4 is marked by a deep median cleft on its buccal surface (White, 1977). All the Hadar specimens for which maxillary premolar root number could be assessed have two roots - buccal and lingual (Ward et al, 1982). Two-rooted maxillary premolars are exhibited by hominids from Makapansgat and by many from Sterkfontein (Robinson, 1956). Robinson (1956) has recorded that eleven of thirteen Sterkfontein P^3s and all of ten

P^4s are two-rooted, while Sperber (1974) has documented this root form in four of seven Sterkfontein P^3s and all of eight Sterkfontein P^4s. The Sterkfontein specimen TM 1511 has two-rooted maxillary premolars (Broom, 1936). Some Swartkrans maxillary premolars, such as the P^4 SK 881 (Sperber, 1974), are two-rooted; of twenty P^3s, five have two roots and of ten P^4s, two - SK 39 and SK 11 - are effectively two-rooted (Robinson, 1956). Sperber (1974) recorded that six of fourteen Swartkrans P^3s have two roots, though he described these roots as mesial and distal! Perhaps some of these are those with show fusion between the mesiobuccal and lingual roots. Two-rooted maxillary premolars have also been described for the following hominid specimens: KNM-ER 1470, KNM-ER 1813, Omo L.894-1, the Rabat maxillary fragment, Sinanthropus P^3 no. 19, Sangiran 15, Krapina specimens (Boaz & Howell, 1977; Day et al, 1975, 1976; Howell, 1960; Jacob, 1972, 1973; Kallay, 1963; Weidenreich, 1937). In an outline of the genus Pithecanthropus, the maxillary premolars were described as occasionally exhibiting two or three roots (Jacob, 1975).

The overriding occurrence of three-rooted maxillary premolars in the Swartkrans australopithecines and of two-rooted maxillary premolars in the Sterkfontein australopithecines has led to the identification of the three-rooted form with Paranthropus and the two-rooted form with Australopithecus (Kustaloglu, 1961; Robinson, 1956). Noting that the three-rooted form represents the primitive condition and working on the assumption that Sterkfontein is geologically older than Swartkrans, Robinson (1956) has commented "this very materially increases the significance of the above differences,

which, under the circumstances, can only mean that the ape-men from these two sites are on separate lines of evolution".

Fusion between the buccal and lingual roots of a two-rooted maxillary premolar leads to the formation of a single root. One Sterkfontein P^3 - Sts 47 - has a single root (Robinson, 1956; Sperber, 1974), and the Rabat P^4 and most of the Sinanthropus maxillary premolars for which root form could be assessed were single-rooted (Howell, 1960; Weidenreich, 1937). In some Sinanthropus maxillary premolars, the buccal and lingual roots are fused for most of their height but show separate apices (Weidenreich, 1937; Woo & Chia, 1954).

In modern human populations, the maxillary premolars - particularly P^3 - usually exhibit some variation in root form. For this reason, some authors describe P^3 as typically two-rooted (Diamond, 1952; Kraus et al, 1969; Scott & Symons, 1974) whilst others describe it as typically single-rooted (Duckworth, 1923; Tomes, 1923). P^4 is unanimously typified as single-rooted, though showing occasional root division (Barker et al, 1973; Diamond, 1952; Kraus et al, 1969; Scott & Symons, 1974; Tomes, 1923).

Single-rooted maxillary premolars may exhibit longitudinal grooves on the mesial and distal root surfaces which vary in their degree of expression - they may be slight, if present at all, or they may be deep (Abrahams, 1946-47; Gher & Vernino, 1980; Kraus et al, 1969; Nelson, 1938; Scott & Symons, 1974; Shaw, 1931; Tomes, 1923; Tratman, 1950). These grooves tend to be less marked and less common in P^4 than P^3, and whilst in

P^3 the mesial root groove is usually more marked than the distal, in P^4 the converse applies (Kraus et al, 1969; Nelson, 1938; Pedersen, 1949; Scott & Symons, 1974; Tratman, 1950; Visser, 1943b). Perceptible to marked mesial root grooves have been recorded in about 50% of East Greenland Eskimo P^3s (Pedersen, 1949), and deep distal root grooves were observed in 40.9% of P^4s in the Teso of Uganda (Barnes, 1969). In single-rooted maxillary premolars, one or two root canals may be present (Barker et al, 1973; Scott & Symons, 1974). Increased development of the mesial and distal root grooves is associated with root division, and the degree of bifurcation is very variable - ranging from apical bifurcation to the formation of separate buccal and lingual roots (Diamond, 1952; Kraus et al, 1969; Scott & Symons, 1974; Taylor, 1899; Turner, 1981). In two-rooted maxillary premolars, a longitudinal root groove may be present on the buccal and/or lingual surfaces of the buccal root, and in very rare instances, deepening of these grooves is associated with bifurcation into mesiobuccal and distobuccal apices/roots (Barker, 1973; Diamond, 1952; Gher & Vernino, 1980; Scott & Symons, 1974; Tomes, 1923; Turner, 1981; Visser, 1943b). Three-rooted maxillary premolars have been documented in modern man, (Abrahams, 1946-47; Armitage, 1971; Brabant, 1963, 1965; Brabant et al, 1953, 1961; De Terra, 1905, cited by Duckworth, 1923; Fabian, 1928, cited by Pedersen, 1949; Gher and Vernino, 1980; Ingle, 1965, cited by Barker et al, 1953; Nelson, 1938; Shaw, 1931; Visser, 1943b). Unusual three-rooted maxillary premolars have been described in which two roots are lingual in position (Barker, 1973; Sculley, 1979).

The continuous nature of maxillary premolar root bifurcation leads to problems in the classification of these teeth according to root number and can lead to a lack of comparability between the frequencies reported by different authors. Illustrating this point, Turner (1981) compared his frequencies for P^3 root number in a sample with those of another author (Wright, 1977, cited by Turner, 1981) for the same sample; the use of slightly different definitions for root number classification by these authors resulted in root number frequencies which were significantly different ($P < 0.001$). To overcome this problem, Turner (1981) has urged the adoption of a standardized classification for maxillary premolar root number, and has himself devised a classification for P^3 which he feels has biological significance and inter- and intra- observer reliability.

The incidence of maxillary premolar root number variates differs in modern human populations (Tables 11 and 12), but in all, root bifurcation is more frequent and more marked in P^3 than in P^4 (Barker *et al*, 1973; Brabant, 1969; Brabant *et al*, 1953; Nelson, 1938; Tomes, 1923; Tratman, 1950; Turner, 1981). In Asian and Asian-derived populations, P^3 tends to show a relatively low incidence of root bifurcation (Nelson, 1938; Pedersen, 1949; Tratman, 1950; Turner, 1981) in comparison to European Caucasian populations, where some degree of root division for P^3 is generally more usual than a single root (Abrahams, 1946-47; Brabant, 1969; Fabian, 1928, cited by Pedersen, 1949; Gher & Vernino, 1980; Ingle, 1965, cited by Barker *et al*, 1973; Selmer-Olsen, 1949; Taylor, 1899; Visser, 1943b). In comparison with the high incidence

Table 11 : The percentage incidence of $P^{\underline{3}}$ root variations in modern man

	N	1 root	2 partially fused roots	2 roots	3 roots	Reference
East Greenland Eskimo	99	95.0	5.1	-	-	Pedersen, 1949
Pecos Pueblo Indians	132	66.7	19.7	11.4	2.3	Nelson, 1938
Dutch	3213	56.0	11.4	29.8	2.8	Visser, 1943b
Lapps (male & female)	473	49.9	40.0	10.1	-	Selmer-Olsen, 1949
(male)	204	42.2	42.6	15.2	-	Selmer-Olsen, 1949
(female)	203	56.7	39.4	3.9	-	Selmer-Olsen, 1949
American?	-	43.0	33.0	22.0	2.0	Ingle,1965,cited Barker et al, 1973
Europeans	-	33.1	16.0	50.6	0.9	Fabian,1928,cited by Pedersen, 1949
Calvinia & Namqualand	52	28.9	13.5	50.0	7.7	Abrahams, 1946-47
Bantu	84	17.9	17.9	57.1	7.1	Shaw, 1931
Australian Aborigines	100	31.0	13.0	56.0	-	Campbell, 1925

Table 12 : The percentage incidence of $P^{\underline{4}}$ root variations in modern man

	N	1 root	2 partially fused roots	2 roots	3 roots	Reference
East Greenland Eskimo	97	99.0	1.0	-	-	Pedersen, 1949
Pecos Pueblo Indians	171	88.9	8.8	1.8	0.6	Nelson, 1938
Dutch	4000	93.4	5.2	3.6	0.3	Visser, 1943b
Lapps (male & female)	430	84.4	15.1	0.5	-	Selmer-Olsen, 1949
(male)	198	79.3	19.6	1.0	-	Selmer-Olsen, 1949
(female)	181	88.4	11.6	-	-	Selmer-Olsen, 1949
Europeans		81.9	11.4	6.7	-	Fabian, 1928, cited by Pedersen, 1949
Calvinia & Namaqualand	54	46.3	24.1	29.6	-	Abrahams, 1946-47
Bantu	83	41.0	18.1	37.4	3.6	Shaw, 1931
Australian Aborigines	93	82.8	7.5	9.7	-	Campbell, 1925

of single-rooted $P^{\underline{4}}$ in most European Caucasian populations, the people of Calvinia and Namaqualand show a conspicuously lower incidence (Abrahams, 1946-47). In African populations and the Australian Aborigines, the incidence of single-rooted $P^{\underline{3}}$ tends to be lower than in European populations, and the incidence of single-rooted $P^{\underline{4}}$ in the Bantu is the lowest documented for a human population (Barnes, 1969; Campbell, 1925; Shaw, 1931; Turner, 1981). Again, Turner (1981) has illustrated the necessity of a standardized premolar root classificiation; in a comparison between Australian Aborigines and Micronesians, the incidence of two-rooted $P^{\underline{3}}$ in the former was either significantly greater or indistinguishable from the incidence in the latter, depending upon how two-rootedness was defined. Three-rooted maxillary premolars are encountered very rarely in some human populations (Tables 11 & 12), being more frequently found in $P^{\underline{3}}$ than $P^{\underline{4}}$.

A study on maxillary premolar root number has indicated that there is independence between $P^{\underline{3}}$ root number and $P^{\underline{4}}$ root number, suggesting the operation of independent genetic factors for each tooth (De Magalhaes et al, 1974). Some evidence of asymmetry was also found; De Magalhaes et al (1974) suggested that, while the same genetic factor is responsible for root number on both sides of the maxilla, its expressivity results in differences in observed frequencies between the two sides. In this study, and also in the Norwegian Lapps (Selmer-Olsen, 1949), females showed lower frequencies of double-rooted premolars than males, but no association was established between sex and maxillary premolar root number. According to De Magalhaes et al (1974), the simplest hypothesis

for the inheritance of root number is that it is governed by a recessive autosomal gene; however, they did observe a strong correlation between root number in fathers and offspring.

ii) Root reduction in molar roots

In keeping with the pattern described for the generalized eutherian dentition (Butler, 1941; Clark, 1971; Gregory, 1920-21) typical primate, fossil hominid and modern human molars have three roots in the upper jaw - these being mesiobuccal, distobuccal and lingual in position - and two roots in the lower jaw - mesial and distal in position. The roots of a molar are not usually divided as far as the cervical line - there is an undivided root part commonly referred to as the root body which, in the case of the human M^1 for example, usually occupies about one-third of the total root height (Kraus et al, 1969; Scott & Symons, 1974; Tomes, 1923; Tratman, 1950). Developmentally, root number is determined by the number of inter-radicular processes which fuse to form the subpulpal wall, and the height of the root body - or conversely, the height of bifurcation - is determined by the level at which this fusion takes place during root formation. These two aspects of root development, acting together or separately, provide a developmental explanation for the confusing profusion of molar root forms referred to in the literature: fused roots, pyramidal roots, cuneiform roots, prismatic roots, taurodont roots. It is hoped that by considering molar root forms from the viewpoint of the developmental factors acting during their formation that some order and clarification may be brought to

this rather confusing area of dental morphology (Fig. 2).

In descriptions of the modern human dentition, reference has often been made to fusion of molar roots, but it seems that the term 'root fusion' has been applied to a few quite different conditions. Some authors have used this term when a molar appears to have fewer roots than usual as a result of hypercementosis, i.e. where the production of cementum between and around the roots has disguised their separate identities (Abrahams, 1946-47; Ackerman, et al, 1973; Nelson, 1938; Shaw, 1931). Kallay (1963) has used the term 'fusion' to describe the condition when two teeth become fused together during their development. The use of the term 'root fusion' which has most application to this study is when it is used to describe the tendency toward reduction of root number which can be traced to the period of root development. Fusion of molar roots is usually more frequent in the maxilla than in the mandible, but in both jaws its frequency increases from the first to the third molar (Barker, 1973; Diamond, 1952; Drennan, 1929; Kraus et al, 1969; Pedersen, 1949; Scott & Symons, 1974; Taylor, 1899). It is also found in deciduous molars (Barker, 1973; Barker et al, 1975; Jorgensen, 1956; Pearsall, 1900; Visser, 1943a)

During molar root development, fusion of one of the interradicular processes with its counterparts may be delayed; when this occurs, the bifurcation between the two roots adjacent to the process is displaced apically and the amount of this displacement reflects the relative timing of the fusion within the period of root formation. Or, one of the usual complement

Fig. 2 : The developmental basis of molar root forms a) mandibular molars

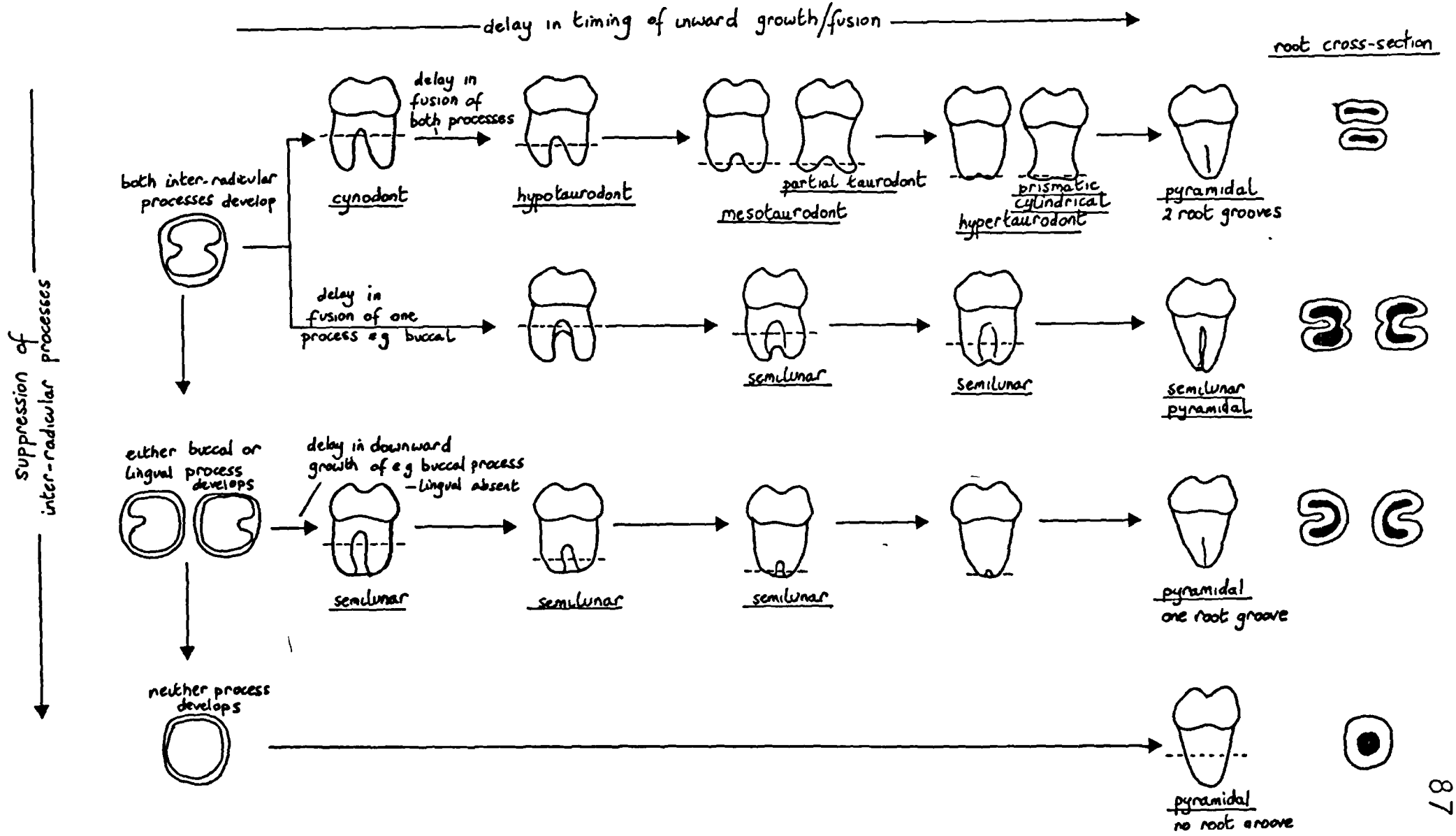


Fig. 2 The developmental basis of molar root forms b) maxillary molars

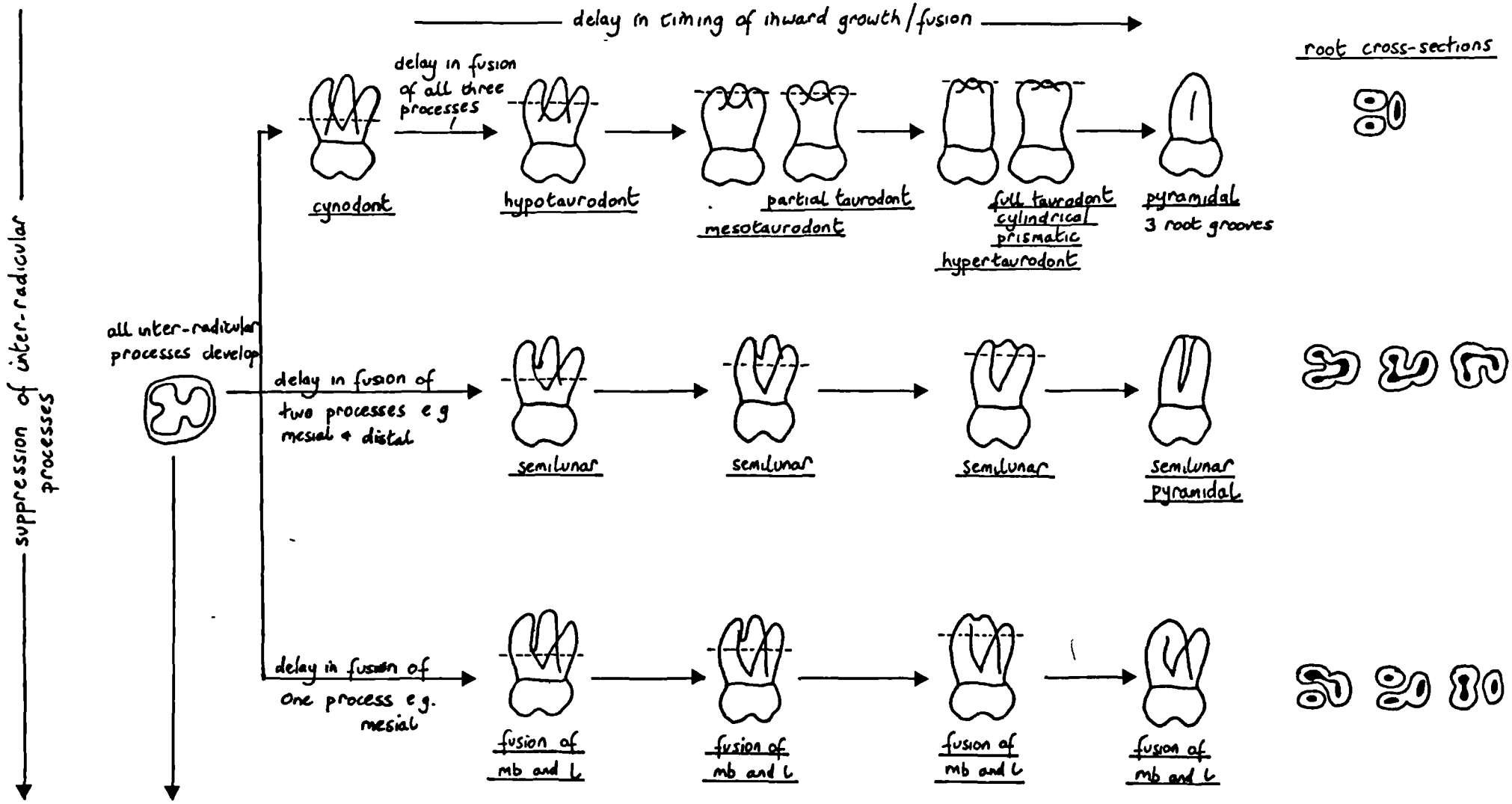
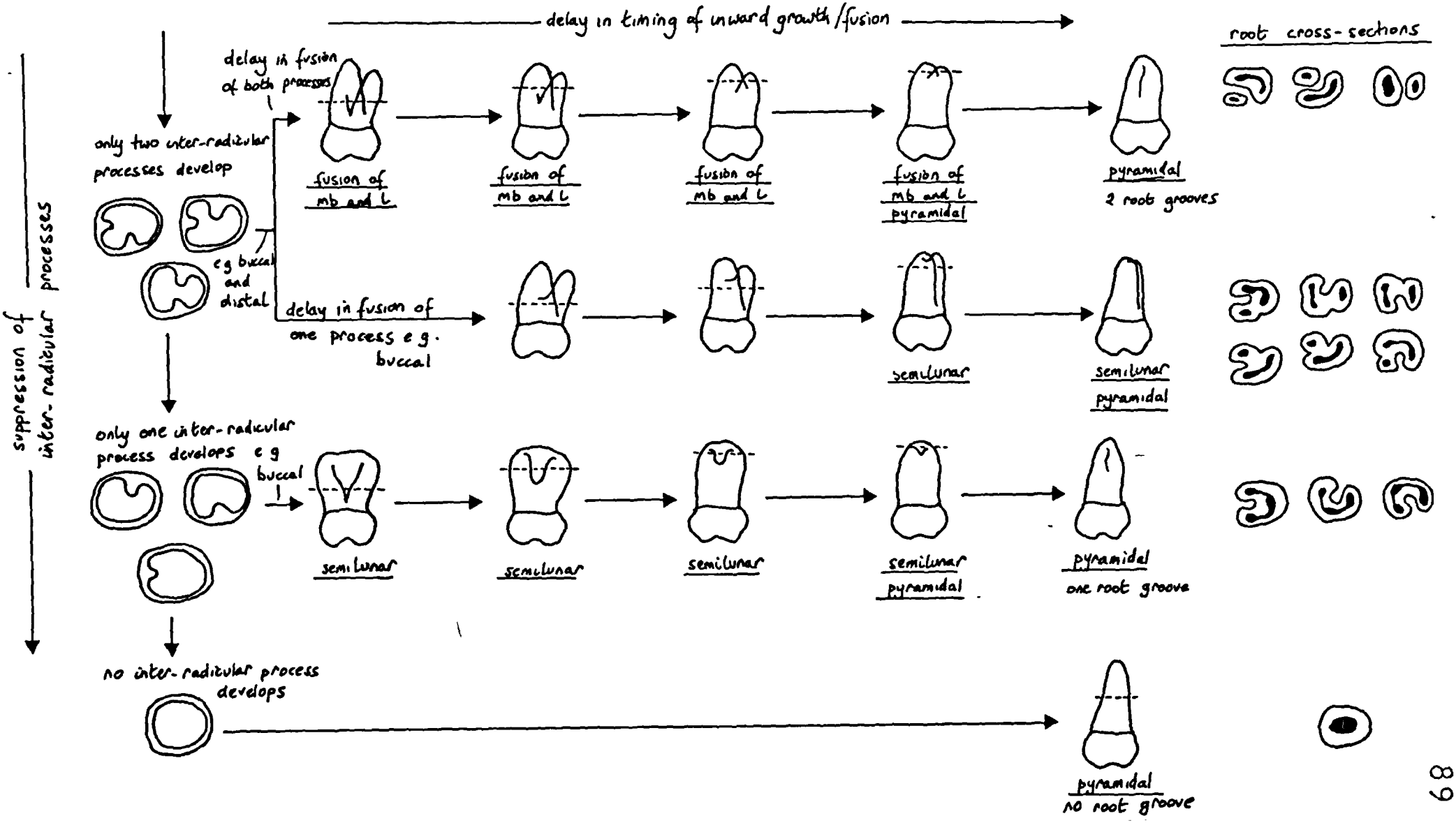


Fig. 2b contd.


delay in timing of inward growth/fusion
root cross-sections
suppression of inter-radicular processes
delay in fusion of both processes
only two inter-radicular processes develop
fusion of mb and L
fusion of mb and L
fusion of mb and L
fusion of mb and L pyramidal
pyramidal
2 root grooves
e g buccal and distal
delay in fusion of one process e g. buccal
semilunar
semilunar pyramidal
only one inter-radicular process develops e g buccal
semilunar
semilunar
semilunar
semilunar pyramidal
pyramidal
one root groove
no inter-radicular process develops
pyramidal
no root groove

of inter-radicular processes may completely fail to develop; this results in complete continuity, from cervical line to apex, between the 'roots' adjacent to the absent process. When the former occurs in mandibular molars, the root and the pulp canal appear horseshoe-shaped in cross-section above the bifurcation; when the latter applies, this cross-sectional shape applies all the way to the apex (Ackerman et al, 1973; Kovacs, 1963; Tratman, 1950). For this reason, this root form has been referred to as the semilunar root (Kovacs, 1963). This type of partial root fusion - partial in the sense that the fusion affects either the buccal or the lingual aspects - has been documented in modern human mandibular molars (Abrahams, 1946-47; Ackerman et al, 1973; Campbell, 1925; Drennan, 1929; Fabian, 1928, cited by Pedersen, 1949; Kovacs, 1963; Nelson, 1938; Pedersen, 1949; Shaw, 1931; Tratman, 1950). Some Sinanthropus mandibular molars exhibit a similar tendency toward root fusion (Weidenreich, 1937; Woo & Chia, 1954). In descriptions of the St. Brelade dentition and La Naulette mandible, the mandibular molars were observed to exhibit a high degree of taurodontism (Keith, 1913); however, the M_2 roots are in fact of semilunar form (Pedersen, 1949; Tratman, 1950). The semilunar root may also be found in maxillary molars, but here it requires the involvement of two inter-radicular processes. In maxillary molars, when the fusion of one of the inter-radicular processes is delayed or when one fails to develop, there is fusion to a lesser or greater extent between the two roots adjacent to this process. This type of partial root fusion - partial in the sense that not all three roots are involved - is well documented in modern human maxillary molars (Abrahams, 1946-47; Campbell, 1925; Drennan, 1929; Fabian, 1928, cited by Pedersen, 1949; Nelson, 1938; Pearsall,

1900; Pedersen, 1949; Selmer-Olsen, 1949; Shaw, 1931; Visser, 1943a). Each of the three combinations of partial root fusion - i.e. between mesiobuccal and lingual roots, between distobuccal and lingual roots, between the two buccal roots - has been recorded in each of the modern human maxillary molars. However, the relative frequency of the combinations differs in the different maxillary molars: in M^1, fusion is most frequent between the distobuccal and lingual roots; in M^2 it is usually most frequent between the mesiobuccal and lingual roots; while in M^3, neither of these combinations usually predominates. In human deciduous maxillary molars, partial root fusion is very common and seems almost invariably to involve the distobuccal and lingual roots (Jorgensen, 1956; Pearsall, 1900; Visser, 1943) Partial root fusion in maxillary molars has also been documented in primates and fossil hominids; fusion between distobuccal and lingual roots has been recorded in the M^2 of Erythrocebus patas, in the maxillary molars of Pan and in the M^3 of Gorilla (Colyer, 1936); and varying types of root fusion have been described in the M^2 L.H.26, the M^3 SK 3977, the M^3 Sangiran 11, the isolated M^2 and M^3 from Trinil and in some Sinanthropus maxillary molars (Dubois, 1924; Jacob, 1973; Sperber, 1974; Weidenreich, 1937; White, 1980).

During molar root development, the fusion of all the usual complement of inter-radicular processes may be delayed so that the level of bifurcation is displaced apically, (Blumberg et al 1967, 1971; Hamner et al, 1964; Kallay, 1963; Kovacs, 1963; Lunt, 1954; Tennant, 1966), and this is the root form which some authors refer to in discussion of taurodontism. The story of taurodontism starts with the discovery, in 1899,

of neanderthal remains at Krapina in Croatia in which an unusual molar root form was noted to be present in about half the population (Gorganovic-Kramberger, 1908). These molars, instead of showing division into separate roots, have each an undifferentiated, more or less cylindrical root which contains a very large pulp chamber, and such roots were described as cylindrical or prismatic. A little later, radiography of the Mauer mandible indicated that, while the molar roots are not prismatic - there being clear differentiation of the roots, the level of root bifurcation is displaced apically so that the root body is unusually deep and contains an enlarged pulp chamber (Schoetensack, 1908, cited by Brabant & Kovacs, 1961). With the Krapina and Mauer specimens in mind, Keith (1913) proposed the term taurodontism to describe molars in which there is "a tendency for the body of the tooth to enlarge at the expense of the roots" and this included prismatic or cylindrical roots as an extreme expression of taurodontism. Keith's definition of taurodontism evidently covers a wide range of variation with respect to the degree to which the bifurcation is displaced apically, and so Shaw (1928) proposed three categories of taurodontism based on the extent of vertical deepening of the root body exhibited by known mandibular molars: hypotaurodontism - the mildest expression - which approximates the degree seen in some South African Bantu-Boskop hybrids; mesotaurodontism, which approximates the degree seen in the Mauer molars; and hypertaurodontism - the most marked expression which approximates the degree seen in some Krapina molars.

According to Tratman (1950), some of the roots figured by Shaw (1928) and described as taurodont are not taurodont, but pyramidal, and a distinction between taurodont and pyramidal

molar roots has been maintained by other authors (Blumberg et al, 1971; Brabant & Kovacs, 1961; Gorjanovic-Kramberger, 1909, cited by Pedersen, 1949; Kovacs, 1963). This difference of opinion stems from different ideas as to what constitutes a taurodont root. To some authors (Keith, 1913; Shaw, 1928), taurodontism is equivalent to apical displacement of the bifurcation. To others (Kovacs, 1963, 1964; Tratman, 1960), taurodontism signifies a distinctive morphology in which the root exhibits a "waist" The formation of a "waist" in taurodont roots results from the tendency for Hertwig's epithelial sheath to enlarge in circumference at some stage during root development (Kovacs, 1963, 1964). Tratman (1950) has distinguished two types of taurodontism: the full taurodont form, in which the unbifurcated root exhibits a waist about half way along the root and so has an hour-glass shape; and the partial taurodont form, in which there is differentiation of separate roots and the waist occurs approximately at the level of bifurcation. The former of these two categories appears to be equivalent to the cylindrical or prismatic root form referred to by early authors before Keith (1913) defined taurodontism.

During molar root formation, some or all of the usual complement of inter-radicular processes may develop but fail to fuse during the period of root development. The resulting molar has a single root which is marked by longitudinal grooves in the locations where the inter-radicular processes have developed. Similar root morphology results when the inter-radicular processes completely fail to develop; the molar is single but unmarked by longitudinal grooves. This root form is the pyramidal root (Brabant & Kovacs, 1961; Kovacs, 1963)

or the pseudo-taurodont root (Tratman, 1950) and is probably equivalent to the 'totally fused root' described in connection with root fusion. Variation of the pyramidal root has been classified into four types on the basis of the external appearance of the root and the number of root canals which it contains (Brabant & Kovacs, 1961; Kovacs, 1963): type A - the pyramidal root is unmarked by root grooves and contains a single pulp canal; type B - same as type A except that the root contains more than one pulp canal; types C and D contain more than one pulp canal and are marked by longitudinal root grooves, these being less marked in type C and more marked in type D. The cuneiform single-rooted molars referred to by Blumberg et al (1971) seem to correspond to type A of this classification and some semilunar roots would be classifiable as pyramidal root type C (Kovacs, 1963). In a Belgian sample, the pyramidal root was found to be very common; it was exhibited by at least one molar in 50% of individuals and was ten times more frequent in females than males (Brabant & Kovacs, 1961). Its frequency increased from the first to the third molar and was twice as common in the maxilla than in the mandible. Pyramidal roots are also common in Indo-Europeans and Mongoloids, particularly the latter (Tratman, 1950). Single-rooted molars, particularly M2 and M3, are well documented in the modern human dentition (Abrahams, 1946-47; Ackerman et al, 1973; Barker et al, 1974; Black, 1902; Brabant, 1969; Campbell, 1925; Fabian, 1928, cited by Pedersen, 1949; Nelson, 1938; Pedersen, 1949; Selmer-Olsen, 1949; Shaw, 1931; Tamse & Kaffe, 1981; Visser, 1943a). In modern human M^3s, three-cusped teeth were frequently observed to have single roots (Black, 1902). The molars of some New World monkeys are typically single-rooted: the M3 of Cebus, and in Callithrix and Hapale jacchus - in which the third

molars are absent - the M2 is typically single-rooted (James, 1960; Owen, 1840-45). In Gorilla, fusion of all three M^3 roots has been recorded (Colyer, 1936). Robinson (1953) has noted that the M_3 of the 'Telanthropus' specimen SK 45 may have been single-rooted, the M^3 root of Hadar specimen A.L.199-1 is of pyramidal form containing a single root canal (Ward et al, 1982) and a similar root form is present in a Sinanthropus M^3 (Weidenreich, 1937).

The subject of taurodontism is further complicated by the fact that there has been a widespread tendency to consider taurodontism as equivalent to enlarged pulp chambers (Ackerman et al, 1973; Arambourg & Hoffstetter, 1963; Blumberg et al, 1967, 1971; Coon, 1963; Drennan, 1945; Hamner et al, 1964; Keene, 1966, Lasker & Lee, 1957; Lysell, 1965; Metro, 1965; Senyurek, 1939). Kallay's (1963) distinction between radicular taurodontism - in which a broad pulp chamber extends along the entire undivided root - and supraradicular taurodontism - which is exhibited by teeth in which there is differentiation of separate roots - is based, at least in part, on features of the pulp chamber. The prismatic root of Blumberg et al, (1971) appears to be more or less equivalent to Kallay's radicular taurodontism, although Blumberg et al also included as prismatic roots which have coalesced through hypercementosis a move which only contributes to the general confusion of molar root terminology. Kallay (1963) remarks that not all Krapina prismatic roots exhibit typical radicular taurodontism - perhaps because some contain more than one pulp canal? The equation of taurodontism with enlarged pulp chambers assumes a close relationship between the height of bifurcation and the height of the pulp chamber - an assumption, as noted by Kovacs (1971),

which is prevalent in the literature. However, there is no one-to-one correspondence between the external and internal root morphology, (Blumberg et al, 1971; Brabant & Kovacs, 1964) and in the deciduous dentition, apical displacement of the bifurcation was not always accompanied by apical displacement of the pulp chamber floor (Jorgensen, 1956). There is a danger in basing the assessment of taurodontism on the pulp chamber in that its size is affected by a number of factors. Firstly, the size of the pulp chamber reduces during tooth development as a result of primary dentine formation (Ackerman et al, 1973; Philippas, 1961; Senyurek, 1939, 1953), and then it may be further reduced through the deposition of secondary dentine in response, it has been suggested, to age or attrition or caries or the presence of dental restorations (Ackerman et al, 1973; Blumberg et al, 1971; Brabant & Kovacs, 1961, 1964; Campbell, 1925; Kovacs, 1971; Pedersen, 1949; Philippas, 1961; Shaw, 1931; Tomes, 1923). In addition, the size of the pulp chamber varies according to molar position; its height generally increases from the first to the third molar as has been noted in primates, the Mauer mandible and modern man (Ackerman et al, 1973; Keith, 1913; Kovacs, 1971; Schoetensack, 1908, cited by Brabant & Kovacs, 1961; Senyurek, 1939, 1953; Shaw, 1928; Tennant, 1966). For these reasons, great care should be exercised in assessing taurodontism based on the size of the pulp chamber; particularly, authors have noted that consideration should be given to age - failure to do this has led to errors in the assessment of taurodontism (Ackerman et al, 1973; Pedersen, 1949; Senyurek, 1939; Shaw, 1928). It is worth noting that the Krapina mandible so frequently figured in works on taurodontism shows incomplete development of molar roots.

These considerations have led some authors to recommend that the diagnosis of taurodontism should be based on the external morphology (Kovacs, 1971; Shaw, 1928), though Blumber et al (1971) do not agree. However, just as the height of the pulp cavity varies according to tooth type, so too does the height of bifurcation (Frederiksen & Hegdahl, 1963, cited by Kovacs, 1971; Keith, 1913; Shaw, 1928), and so Shaw has suggested that, when assessing taurodontism, only like teeth should be compared with each other, i.e. $M\overline{1}$ with $M\overline{1}$, etc., and that the diagnosis of taurodontism in an individual should be based on its expression in $M\overline{2}$.

Some studies have attempted to assess taurodontism from a metrical viewpoint. In the deciduous dentition, a molar was considered to exhibit partial taurodontism when the height of bifurcation exceeded 2.5 mm in $dm\overline{2}$ or 3.0 mm in the other deciduous molars (Jorgensen, 1956); Brabant & Kovacs (1964) have suggested that a limit of 4 mm would be more appropriate. Keene (1966) has suggested that the diagnosis of taurodontism should be based on the taurodontism index, which expresses the height of the pulp chamber as a percentage of root height, and has used the following values of this index to quantify Shaw's (1928) classification of taurodontism: cynodont 0-24.9% hypotaurodont 25.0-49.9%; mesotaurodont 50.0-74.9%; hypertaurodont 75.0-100.0%. Other authors have used a similar approach (Holt & Brook, 1979; Shifman & Chanannel, 1978). Blumberg et al (1967, 1971) used a number of crown and root measurements to derive a series of discriminant functions whic define taurodontism; of the measurements taken, the major discriminatory variables proved to be neck mesiodistal diameter a the perpendicular distance between the neck and the highest

point on the pulp chamber floor (Blumberg et al, 1971).

A central theme in the early discussions of taurodontism has been the evolutionary significance of this root form. As taurodontism was considered by some early authors (Adloff, 1908, cited by Keith, 1913; Keith, 1913) to represent a specialization and to be characteristic of the neanderthal dentition, neanderthal man was excluded from modern man's ancestry - rather, the relationship between these two groups was thought to be collateral. This opinion was held, though not by all authors (Gorjanovic-Kramberger, 1908), even though it was recognised that the degree of taurodontism varied widely in the neanderthal dentition and that taurodontism had been recorded in modern human molars (Adloff, 1908, cited by Keith, 1913; Gorjanovic-Kramberger, 1908). The idea that taurodontism was not found in the modern human dentition, except in rare instances and only to a minor degree, was refuted by Shaw (1928) who recorded hypo- and meso-taurodontism with a frequency of about 30% in some living South African groups and who also observed examples of hypertaurodont molars. Taurodontism has since been recorded in modern man, for both the deciduous and permanent dentitions, on many occasions (Ackerman, et al, 1973; Barker et al, 1975; Barnes, 1969; Blumberg et al, 1967, 1971; Brabant, 1963, 1965; Brabant & Kovacs, 1961; Coon, 1963; Crawford, 1970; Dahlberg, 1970; Drennan, 1945; Durr et al, 1980; Gamer & Zusman, 1967; Hamner et al, 1964; Holt & Brook, 1979; Jorgensen, 1956; Keene, 1966; Lasker & Lee, 1957; Lunt, 1954; Lysell, 1962, 1965; Mangion, 1962; Mason-Hing, 1963; Metro, 1965; Pedersen, 1949; Shifman & Chanannel, 1978; Stoy, 1960; Tennant, 1966;

Tobias, 1955; Tratman, 1950). It has been suggested that there may be racial difference in the frequency of taurodontism (Blumberg et al, 1967; Brabant & Kovacs, 1961; Jorgensen, 1956). Even though he acknowledged its infrequent occurrence in Caucasians, Coon (1963) proposed that taurodontism is found in modern peoples who are related to the Mongoloid or Capoid races; according to Hamner et al (1964), this view can no longer be substantiated.

The identification of taurodontism in the modern human dentition led to the proposal that modern man had evolved from a form in which the molars were moderately taurodont, though some still maintained that the presence of hypertaurodontism in the neanderthal dentition was evidence of specialization (Gregory, 1920-21; Pedersen, 1949; Shaw, 1928). However, the idea that taurodontism is a character of evolutionary significance has not always found acceptance (Robinson, 1956). Howell (1967, cited by Blumberg et al, 1971) has commented that enlarged pulp cavities predominated in early men with gradual reduction throughout the Pleistocene. However, published information suggests the absence of taurodontism in australopithecines; hypo- and meso-taurodontism has been recorded in australopithecine molars, but this may only be a reflection of larger tooth size (Kustaloglu, 1961; Robinson, 1956; Sperber, 1974). Taurodontism was not observed in the dentition of the Omo cranium L894-1, a specimen which may represent an early species of Homo (Boaz & Howell, 1977). It seems to be accepted that the Middle Pleistocene hominids Sinanthropus and Atlanthropus display taurodontism (Arambourg & Hoffstetter, 1963; Coon, 1963; Kustaloglu, 1961); some Atlanthropus molars have been described as showing marked

taurodontism (Arambourg & Hoffstetter, 1963) yet the illustrations indicate that if taurodontism is present at all, it is slight. As previously noted, taurodontism of varying degrees is said to be exhibited by neanderthal and other late hominids such as St. Brelade, La Naulette, Montmaurin, Gibraltar, Steinheim, Spy, Heidelberg and Krapina (Arambourg & Hoffstetter, 1963; Bryce, 1913; Coon, 1963; Howell, 1960; Howell, 1967, cited by Blumberg et al, 1971; Kallay, 1963; Keith, 1913; Vallois, 1956).

It has been suggested that generally the roots of primate molars are cynodont (Jorgensen, 1956; Keith, 1913; Pedersen, 1949; Senyurek, 1939). It has further been suggested that cynodontism is a basal primitive feature for all primates, being found not only in living members of the suborder Lemuroidea, but also in the fossils Adapis, Notharctus, Pelycodus and Necrolemur (Senyurek, 1939, 1953). However, taurodontism has been recorded in some South American monkeys and in pongids (Senyurek, 1939, 1953).

Some authors have suggested that taurodont roots, and also pyramidal and fused roots, offer a selective advantage in relation to diet; the apical displacement of the bifurcation may allow prolonged life of the tooth by delaying its loss through periodontal disease as this accelerates once the bifurcation is exposed to the oral cavity (Blumberg et al, 1971, Coon, 1963; Keith, 1913; Kovacs, 1971). It has also been proposed that taurodontism is a continuous trait without discrete modes of expression, and within a wider context, that taurodontism and fused molar roots represent transitional forms

in a continuum of which cynodontism represents one extreme and pyramidal roots the other (Ackerman et al, 1973; Blumberg et al, 1971). Of particular interest is the proposal of Ackerman et al (1973) which equates the presence of these molar root forms with a tendency toward root unification and reduction - this being compatible with Jorgensen's (1956) suggestion that incomplete separation of the roots in both the deciduous and permanent dentitions represents reduction phenomena in the dentition. In connection with this viewpoint, several cases have been documented in which taurodontism is associated with small size of the crowns and/or roots and with congenital absence of teeth (Casamassimo et al, 1978; Gardner & Girgis, 1977; Holt & Brook, 1979; Sauk & Delaney, 1973; Stenvik & Svatun, 1972; Stoy, 1960), and Keene (1966) noted a three-fold increase in the frequency of single-rooted M_2^{-}s when the adjacent M_3^{-} was congenitally absent.

B : Root increase in incisors, canines and molars

While the question of root reduction has greater application to this thesis, a survey of root variation would be incomplete without documentation of the tendency toward root increase which may be exhibited, to a greater or lesser extent, by any tooth of the dentition. (As premolar root variation has already been discussed in full, it will not be included here). Root increase can arise in two ways; through bifurcatio of existing roots or through the appearance of accessory roots (Brabant et al, 1953; Butler, 1956; De la Parra, 1955; Euler, 1939, cited by Brabant et al, 1953). It has been suggested that the tendency to root bifurcation may be related to root breadth - that once a certain breadth is exceeded, root bifurcation follows (De Jonge, 1965) and this relationship appears to be compatible with the suggested influence of the proximity of blood vessels on the inhibition of the interradicular processes during root development (Butler, 1956). Accessory roots have been suggested to result from defects in Hertwig's epithelial sheath during root development (Butler, 1956). Without distinguishing between root bifurcation and accessory roots, it has been noted that, of the human permanent teeth, molars exhibit the highest frequency of supernumerary roots while these are very rare in the maxillary canine and incisors (Brabant et al, 1953; Euler, 1939, cited by Brabant et al, 1953). In the following survey of root increase, an attempt has been made to distinguish between root bifurcation and the presence of accessory roots, but because of the lack of necessary detail in some published information this may not always have been accurately done.

1) Root increase arising through apical bifurcation

Where additional apices or roots arise through bifurcation, they usually do so in relation to the longitudinal grooves which are present on the root surfaces. These grooves, developed to varying extent and depth, may be found on the mesial and/or distal root surfaces of primates, fossil hominid and modern human permanent incisors, canines, mandibular molars and maxillary molar buccal roots; in the case of maxillary molar lingual roots, the grooves may be found on the buccal and/or lingual root surfaces (Abrahams, 1946-47; Alexandersen, 1962a, 1963; Arambourg & Hoffstetter, 1963; Black, 1902; Black, 1927; Broom & Robinson, 1952; Broom & Schepers, 1946; Campbell, 1925; Colyer, 1936; Day et al, 1976; Diamond, 1952; Gher & Vernino, 1980; Kraus et al, 1969; Leakey et al, 1972; Leakey & Walker, 1973; Owen, 1840-45; Pedersen, 1949; Rightmire, 1980; Robinson, 1956; Scott & Symons, 1974; Shaw, 1931; Tomes, 1923; Ward et al, 1982; Weidenreich, 1937, 1945; White, 1977, 1980). Presumably, every root of the dentition has the propensity to divide through apical bifurcation, but in practice bifurcation of some roots is more common than of others.

Incisors

Although most unusual, the tendency towards root division may be encountered very occasionally in modern human incisors (Barker, 1964; Brabant et al, 1953). In the case of the mandibular incisors, marked deepening of the root grooves and apical bifurcation has been recorded in the Bantu, the people of Calvinia and Namaqualand and in European groups (Abrahams, 1946-47; Brabant et al, 1961; Diamond, 1952; Kraus et al, 1969; Scott & Symons, 1974; Shaw, 1931). Barker (1973)

has described an I_2 in which there were well-developed labial and lingual roots. Incisor root bifurcation has also been documented in Hylobates lar; in one specimen, the I_2 exhibited apical bifurcation, the I^2 showed a tendency towards bifurcation and the dc^1 was two-rooted (Alexandersen, 1962b).

Judging from the frequency of reported cases, it is particularly I^1 of the maxillary incisors which may show root bifurcation; even so, such cases are rare. Examples of I^1s have been described in which two well-formed roots were present, these being separated for at least half the root height (Henry, 1970; Patterson, 1970; Mader & Konzelman, 1980). Other reports have specified that the two roots are labial and lingual; in such cases, the labial root predominates in size over the lingual root which may be rudimentary or well-formed (Barker, 1964, 1973; Brabant et al, 1953; De Jonge, 1961a; Zaslawsky, 1937). In one of these reports (Henry, 1970), the presence of two roots was noted to be associated with a larger-than-normal root to the antimere and larger-than-normal crowns to both I^1s. A connection between I^1 root division into mesial and distal roots - examples of which are sometimes found - and the presence of the coronal-radicular groove has been suggested (Brabant, 1971), the latter being a marked groove or furrow which extends from the lingual crown surface onto the root (De Jonge, 1961a; Kraus et al, 1969). Barker (1964) has remarked that partial division or elaboration of the lingual cingulum has been noted in specimens of two-rooted I^1. The only recorded case of a human I^2 with two roots appears to be that illustrated by Diamond (1952). Examples of di^1 root bifurcation have been documented, but in such teeth the apices are mesial and distal (De Jonge, 1961a; De la Parra,

1955). Visser (1948, cited by De Jonge, 1961a) has recorded a frequency of about 7% for di$\frac{1}{-}$ root bifurcation.

Canines

In the modern human dentition, two-rooted mandibular canines are generally accepted as not-so-unusual variants of canine morphology (Alexandersen, 1963; Barker, 1973; Black, 1902; Diamond, 1952; Duckworth, 1923; Kraus et al, 1969; Scott & Symons, 1974). With respect to root grooves and bifurcation, mandibular canine morphology represents a continuum of expression ranging from single-rooted teeth with slight indications of root grooves to two-rooted teeth in which the roots are well developed (Alexandersen, 1963; Barker, 1973; Kraus et al, 1969). Because of their relation to the proximal root grooves, the apices or roots are labial and lingual, and it is usually the lingual which is the smaller (Alexandersen, 1962a, 1963; Diamond, 1952; Le Huche, 1954). A tendency towards asymmetric expression of two-rooted mandibular canines has been noted by a few authors (Alexandersen, 1962b, 1963; Harborow 1934; Selmer-Olsen, 1949). Isolated examples of two-rooted mandibular canines have been documented in several dental case reports (Barker, 1973; Barker et al, 1973; Bloch, 1936; Brabant et al, 1953; Harborow, 1934; Oringer, 1948). The frequency of two-rooted mandibular canines may vary between different human populations. The reported frequencies for European populations generally range between 5% and 10%, and it seems that two-rooted mandibular canines were particularly frequent in earlier times than in the present day (Fabian, 1928; Hillebrand, 1909; Hjelmann, 1929; Schwerz, 1916; Visser, 1948, all cited by Alexandersen, 1963; Alexandersen, 1963; Brabant et al, 1961;

Duckworth, 1923; Le Huche, 1954; Peyer, 1968; Selmer-Olsen, 1949). In the Norwegian Lapps (Selmer-Olsen, 1949), a higher frequency was recorded in females (5.5%) than males (2.7%). In comparison, only isolated examples of two-rooted mandibular canines have been documented in the people of Calvinia and Namaqualand, the Bantu and the East Greenland Eskimo, while some have been observed in the Teso of Uganda, the Pecos Pueblo Indians and the Australian Aborigines (Abrahams, 1946-47; Barnes, 1969; Campbell, 1925; Nelson,1938; Pedersen, 1949; Shaw, 1931). Alexandersen (1962b, 1963) has compared the European frequency with those of some other human groups; the European frequency proved to be significantly different ($P < 0.01$) from that found in the Pecos Pueblo Indians, but not from that found in the Bantu or in the East Greenland Eskimo.

No reference to two-rooted mandibular canines in fossil hominids has been found in the literature, and this root form appears to be most uncommon in primate species. Alexandersen (1962b, 1963) examined various primate species and could find no examples of two-rooted mandibular canines, but the sample sizes were small. Schwarz (1931, cited by Alexandersen, 1963) has illustrated a female Pan specimen with a two-rooted mandibular canine, but contrary to the disposition found in human specimens the apices were mesial and distal. In connection with this observation, it has been noted that Gorilla mandibular canines may have longitudinal grooves on the labial and lingual root surfaces (Remane, 1921, cited by Alexandersen, 1962b). A two-rooted mandibular canine has apparently been recorded for a specimen of Cynocephalus (De Terra, 1905, cited by Duckworth, 1923), and a two-rooted $dc\bar{1}$ has been observed in a

specimen of Hylobates lar (Alexandersen, 1962b).

According to Alexandersen (1962a, 1963), two-rooted mandibular canines result from the effect of the morphogenetic field governing root development in multi-rooted teeth being extended to the canine region; Harborow (1934) has documented the associated presence of two-rooted mandibular canines and three-rooted premolars in an individual.

The infrequence of comment in the literature on root bifurcation of the modern human maxillary canine supports the view that this is much more infrequent than in the mandibular canine (Alexandersen, 1962a; Brabant et al, 1953). However, in two human populations - the Bantu and the people of Calvinia and Namaqualand - a higher incidence of root bifurcation was found in the maxillary canine than in the mandibular canine (Abrahams, 1946-47; Shaw, 1931). Other examples of bifurcated human maxillary canine roots have been recorded (Brabant et al, 1953, 1961). In the East Greenland Eskimo and Pecos Pueblo Indians, all maxillary canines were single-rooted (Nelson, 1938; Pedersen, 1949). Examples of two-rooted deciduous maxillary canines have been reported in which the apices are mesial and distal (Bimstein & Bystrom, 1982; Brown, 1975; Bruszt, 1964; Chow, 1980; De Jonge, 1961a; Kelly, 1978; Krolls & Donahue, 1980).

Two-rooted maxillary canines have been observed in Cynocephalus, and a tendency for root bifurcation of dc^1 has been recorded in Hylobates and Pan (De Terra, 1905, Remane, 1960, both cited by Alexandersen, 1962b). Two-rooted

maxillary canines are found in some modern prosimians, tree-shrews and insectivores and have been recorded in the Paleocene primates Navajovius and Phenacolemur (Alexandersen, 1962b, 1963; Butler, 1948; Clark, 1971; Duckworth, 1923; James, 1960; Lyon, 1913; Owen, 1840-45; Swindler, 1976).

Molars

In modern human mandibular molars, apical bifurcation occurs most frequently in M_1, being more uncommon in M_2 and M_3, but in each molar the mesial root is more frequently bifurcated than the distal root (Barker et al, 1974; Diamond, 1952; Kraus et al, 1969; Tomes, 1923). A high incidence of mandibular molar apical bifurcation has been observed in the Australian Aborigines; the M_1 mesial root was almost invariably bifurcated in its lower quarter, the M_1 distal root was very frequently bifurcated, while apical bifurcation of the M_2 mesial root was not uncommon (Campbell, 1925). In the Teso of Uganda, the M_1 mesial root exhibited an apical bifurcation of 2-3 mm in about 35% of specimens (Barnes, 1969), but in the Bantu, bifurcation of this root was not observed (Shaw, 1931). Apical bifurcation of the M_1 mesial root is also encountered in Caucasian populations with a frequency, it seems, of up to about 10% (Abrahams, 1946-47; Bolk, 1915a, De Souza-Freitas et al, 1971; Tratman, 1950; Visser, 1948, cited by De Souza-Freitas et al, 1971). While bifurcated mandibular molar roots were not observed in the East Greenland Eskimo and the Pecos Pueblo Indians, they have been in other Mongoloid groups (De Souze-Freitas et al, 1971; Nelson, 1938; Pedersen, 1949; Somogyi-Csizmazia et al, 1971; Tratman, 1950). Where apical bifurcation is more than

minimal, the molar will have the appearance of being three-rooted if one root alone is bifurcated or four-rooted if both roots are affected (Black, 1902; Bolk, 1915a; Diamond, 1952; Tomes, 1923). Examples of three- and four-rooted molars have been recorded in both the permanent and deciduous dentition though it is not always clear whether these have arisen through bifurcation of the main roots or through the presence of an accessory root (Badger, 1982; Barker, 1973; Birnbaum, 1936; Brabant et al, 1953; Kraus et al, 1969; Mackinstry, 1936; Pleshette, 1921; Tratman, 1938, 1950).

In hominid mandibular molars - just as in the human dentition - deepening of the root grooves may be associated with apical bifurcation. In this connection, the exposed mandibular molar root cross-sections of some fossil hominids have been described as dumbell-shaped or bilobed (Leakey & Wood, 1974a, 1974b; Ward et al, 1982; White, 1977), which suggests that root bifurcation could be present at a more apical level. In Swartkrans specimens - e.g. SK 828, SK 843 - the M_1 mesial root is usually bifurcated, and additionally, the M_1 distal root may also be bifurcated as in SK 838b and SK 846a (Broom & Robinson, 1952; Robinson, 1956; Sperber, 1974). The M_1 of KNM-ER 1816 has been described as four-rooted (Day et al, 1976), so it seems that this specimen shows extensive bifurcation of the mesial and distal roots. In Hadar specimens, the mesial root of each molar displays apical bifurcation (Johanson et al, 1982; Ward et al, 1982). Other examples of apical bifurcation in early hominid mandibular molars have been described: the M_2 mesial root of TM 1600a and Omo L44-2466, the M_2 distal root of SK 1, and the M_3 mesial roots of TM 1518, SK 841b and Omo L33-9 (Coppens, 1970, 1973a; Robinson, 1956;

Sperber, 1974). The mandibular molars of Atlanthropus exhibit apical bifurcation in one or both roots (Arambourg & Hoffstetter 1963), and in the M_1 and M_2 of Sinanthropus the mesial root is bifurcated (Weidenreich, 1937; Woo & Chia, 1954). There is very little information on primate mandibular molar roots; James (1960) has described a Papio specimen in which the M_3 had either an additional root or a bifurcation of the distal root.

In the modern human dentition, apical bifurcation appears to be much less frequent in maxillary molar roots than in mandibular molar roots. Bifurcation of the lingual root has been observed in M^1 and M^2 (Black, 1902; Bolk, 1915b, cited by Jorgensen, 1956; Brabant et al,1953; Diamond, 1952; Thews et al, 1979). A relationship between bifurcation of the lingual root and crown size has been suggested, but not always accepted (Barker, 1973; Butler, 1956; De Jonge, 1965). De Jonge (1965) has proposed that when an M^2 or M^3 has four roots, the additional root results - not from bifurcation of the lingual root - but from bifurcation of the mesiobuccal root. Examples of bifurcated mesiobuccal roots in M^1 and M^2 have been recorded, and a tendency for bifurcation of this root was noted in the Australian Aborigines (Brabant et al, 1953; Campbell, 1925; Kraus et al, 1969). In M^1 the mesiobuccal root contains two pulp canals in 42% of specimens (Pinenda, 1973). Colyer (1936) has described Pan M^3s in which the mesiobuccal root showed a tendency toward bifurcation and in which there was marked grooving of the lingual root. The M^1 lingual root of O.H.5. shows slight apical bifurcation (Tobias, 1967). Examples of human M^3s have been described in which there

is multiple subdivision of the roots (Barker, 1973; Black, 1902), and these are reminiscent of the maxillary molars of Sterkfontein hominid Stw 53 in which each root, particularly the mesiobuccal, of each molar shows a marked tendency toward bifurcation (Hughes & Tobias, 1977).

ii) Root increase arising through accessory roots

Accessory roots have been described as those which bear off cervically from the base of a main root as rudimentarily developed roots, and it has been suggested that they can occur throughout the dentition (De Jonge, 1943, cited by De la Parra, 1955). However, in comparison to the incidence of one particul accessory root - the distolingual root of the mandibular molars all others appear to be very sporadic in occurrence.

Only a couple of references have been found which relate to accessory roots in human incisors and canines: an $I_{\bar{1}}$ has been documented in which there was an accessory labial rootlet (Barker, 1973); and in two-rooted mandibular canines, the additional root occasionally appears as an accessory root issuing off the main root, rather than being the product of apical bifurcation (Hillebrand, 1909, cited by Alexandersen, 1962a; Kraus et al, 1969).

In human mandibular and maxillary molars, accessory roots may be found between the main roots in the region of the bifurcation (Abrahams, 1946-47; Barker, 1973; Bolk, 1915a; Brabant et al, 1953; Campbell, 1925; De Jonge, 1943, cited by De la Parra, 1955; Mackinstry, 1936; Oringer, 1948; Pedersen

1949; Stein, 1936), and Butler (1956) has referred to these as intercalary roots. Similar accessory roots have been documented in Pan $M^{\overline{3}}$s and in Pongo $dm_{\overline{2}}$s (Colyer, 1936). In human third molars, a small accessory root which branches off one of the main roots is not uncommon (Kraus et al, 1969), and in maxillary molars, an accessory root may be associated with the presence of the Carabelli tubercle (Stein, 1936). However, none of these molar accessory roots appears to be comparable in frequency to the distolingual root of mandibular molars.

In mandibular molars, a distolingual accessory root may be found which is located distally, lingual to the distal root, and while its size and shape may vary considerably, it is usually smaller than the distal root, slender, circular in cross-section and curved (Bolk, 1915a; Buchner & Kaffe, 1978; Curzon et al, 1971; Jones, 1980; Kraus et al, 1967; Madeira et al, 1964; Pedersen, 1949; Reichart & Metah, 1981; Tratman, 1938, 1950). Usually it arises close to the cervical line and projects lingually before curving back toward the distal root (Bolk, 1915a; Curzon et al, 1971; Pedersen, 1949; Turner, 1971). The accessory distolingual root may be expressed either symmetrically or asymmetrically (De Souza-Freitas et al, 1971; Hochstetter, 1975; Pedersen, 1949; Tratman, 1938; Turner, 1971), and while Tratman (1938) has commented that when expressed asymmetrically it is more common on the right, Turner (1971) has noted no side preference. The presence of the distolingual root in $M_{\overline{1}}$ has been noted to be associated with reduced root height and root buccolingual diameter of both the mesial and distal roots and increased neck buccolingual diameter (Madeira

et al, 1964); other authors have commented on reduced size of the distal root when the distolingual root is present (Curzon et al, 1971; Pedersen, 1949; Tratman, 1938). The possible association between the presence of the distolingual root and aspects of crown morphology has received little attention, though it has been observed to be present only in five-cusped M_1^-s (Tratman, 1950). While Turner (1971) considers that the accessory distolingual root arises through bifurcation of the distal root, other authors regard it as a true accessory root (Bolk, 1915a; De Souza-Freitas et al, 1971; Hochstetter, 1975; Tratman, 1938, 1950).

Of the mandibular molars, the distolingual root is most frequently encountered in M_1^- ($3RM_1^-$), but its incidence in this tooth varies considerably in different human populations. The highest frequency for $3RM_1^-$ has been reported for the Aleutians - 43.7% of individuals (Turner, 1971) - and with the exception of the Greenland Eskimos (Curzon, 1974a; Pedersen, 1949), all Eskimo groups exhibit a frequency of greater than 20% (Curzon et al, 1971; Curzon, 1974b; Merbs, 1969, cited by Turner, 1971; Pyle, 1938, cited by Pedersen, 1949; Turner, 1971). Curzon (1974a) has suggested that the $3RM_1^-$ frequencies in Arctic peoples represent a cline, being highest in the West (Aleuts) and lowest in the east (Greenland Eskimos). The Navajo Indians exhibit a frequency of $3RM_1^-$ which is comparable to the Aleuts and Eskimos - 32% (Hylander, 1969, cited by Turner, 1971), 27.3% (Turner, 1971) - while the incidence in North American Indian populations is lower, ranging from 0% to 15.6% (Somogyi-Csizmazia et al, 1971; Turner, 1971). The difference in $3RM_1^-$ frequency between the Aleuts-Eskimos and the non-Navajo American

Indians, which was statistically significant ($P < 0.001$), led Turner (1971) to support the view that Aleuts and Eskimos are closely related and should not be classified with American Indians. He proposed that the differences between the Aleuts-Eskimos, the Navajo Indians and the non-Navajo Indians could be explained by three separate migrations from Asia into America, and these three groups are apparently compatible with recognized New World linguistic divisions. In South American populations, the incidence of $3RM_1^-$ falls within the range reported for North American Indians - 3.7% in Peruvian Indians (Turner, 1971) and 3.2% in Brazilians of mixed descent (Madeira et al, 1964). The reported frequencies for $3RM_1^-$ in Asian Mongoloid populations range from 8% to 20%, being lowest in the Chinese and highest in the Japanese (De Souze-Freitas et al, 1971; Hochstetter, 1975; Jones, 1980; Laband, 1941; Reichart & Metah, 1981; Somogyi-Csizmazia et al, 1971; Tratman, 1938). It has been commented that the distolingual root is rarely found in Europeans (Laband, 1941; Tratman, 1938, 1950), and frequencies of $3RM_1^-$ of up to 3.3% have been recorded in European groups (Bolk, 1915a; Curzon, 1973; De Souza-Freitas et al, 1971; Fabian, 1928; Hjelmann, 1928, both cited by Curzon, 1971; Schwerz, 1916, cited by Pedersen, 1949; Taylor, 1899). In other Caucasian groups, frequencies of 0.3% for Indians and 5.4% for Eurasians have been reported (Tratman, 1938). In the only African group for which a frequency of $3RM_1^-$ has been found - the Teso of Uganda - this was 5.6% (Barnes, 1969).

The accessory distolingual root may also be found in M_2^- and M_3^-, but in most human populations its frequency in these

teeth does not approach its frequency in M_1^- (Adloff, 1914-15, cited by Pedersen, 1949; Barker et al, 1974; Barnes, 1969; Oringer, 1948; Pedersen, 1949; Schwerz, 1916, cited by Pedersen, 1949; Tomes, 1928; Tratman, 1938, 1950). It has also been documented in deciduous mandibular molars (Mayhall, 1981; Jorgensen, 1956; Tratman, 1938); in a Danish sample, all three dm_1^-s which exhibited this accessory root had triangular-shaped crowns (Jorgensen, 1956).

In some human populations, $3RM_1^-$ may be more frequent in males than females (Curzon, 1973; Hochstetter, 1975; Somogyi-Csizmazia et al, 1971); in the Aleut-Eskimo group (Turner, 1971), the difference in incidence between the sexes was statistically significant ($P < 0.01$). However, in people of European and Japanese descent (De Souze-Freitas et al, 1971), and when the world-wide sex means were tested (Turner, 1971), no statistically significant difference in incidence was determined between the sexes. Tratman (1938) has suggested that females tend to show $3RM_1^-$ symetrically while males tend to exhibit a considerable degree of asymmetry. This has been investigated in New World samples (Turner, 1971); when the samples were pooled, females showed a 6% greater incidence of asymmetry than males, but when the samples were assessed separately, males showed more asymmetry than females in six out of the eleven samples.

The genetic basis of the accessory distolingual root may not be the same in all human groups. From observations on Alberta Indians and Eurasians, it has been concluded that the distolingual root is inherited as a sex-linked, dominant character (Somogyi-Csizmazia et al, 1971; Tratman, 1938). Turner (1971) has discounted this mode of inheritance for the

Aleut-Eskimos and has suggested that an X-chromosome recessive allele model is compatible with the observed data.

Part II : Samples & Methods

Chapter 4 : The Samples

Chapter 5 : Methods

Part II

Chapter 4 : The Samples

i) The comparative samples

ii) The fossil hominid sample

Chapter 4 : The Samples

1) The comparative samples

The samples of Gorilla gorilla, Pan troglodytes, Pongo Pygmaeus and Homo sapiens were compiled from the pongid and archaeological collections of the British Museum (Natural History). The modern human sample comprised two sub-samples: Australian Aborigines, and Romano-British from the 4th century A.D. cemetery site of Poundbury Hill, Dorset.

The following samples were defined: 40 specimens of Gorilla gorilla (23 males and seventeen females); 31 of Pan troglodytes (twenty males and eleven females); 34 of Pongo pygmaeus (nineteen males and fifteen females); and 34 specimens of Homo sapiens sapiens (sixteen males and eighteen females). The composition of the modern human sample is as follows: twenty specimens of Romano-British (ten males and ten females) and fourteen of Australian aborigine (six males and eight females). The B.M. (N.H.) specimen number and the sex of each specimen included in the samples are listed in Appendix A.

Only adult specimens were included in the samples, and a specimen was considered to be adult if all the permanent teeth were in occlusion. While it was realized that this criterion might lead to the inclusion of specimens in which all roots would not be fully formed, it was considered justifiable as any immature teeth would be identifiable on the radiographs and so could be omitted from the final tooth samples. However, to increase the liklihood that all roots would be complete, wherever possible specimens were

chosen in which there was demonstrable occlusal wear of the canines and third molars.

In forming the samples, preference was given to specimens which preserved the complete dentition. Otherwise, specimens were included if at least one antimere of each tooth was present. However, in order to avoid unnecessarily small samples, some specimens had to be included in which both antimeres of one or more teeth were absent; this generally applied to incisors, which are commonly lost *post mortem* in dry specimens.

No specimens with obvious pathology were included in the samples, with the exception of localised dental abcesses as, in such cases, measurements could be safely made on the other side of the jaw.

The sex of each specimen was assessed on the basis of cranial characters. If the sex of a specimen was identified in the museum records, this was noted and used as a check against the author's diagnosis. Where a discrepancy arose between the two diagnoses, the specimen was reassessed. Having selected specimens on the basis of the criteria previously mentioned, none were then excluded on the grounds of uncertain sexual identification. All specimens were categorized as either male or female, even when the attribution was uncertain. This was done to avoid the possible exaggeratio of sexual difference in the data.

ii) The fossil hominid sample

The fossil hominid sample was made up of specimens representing the permanent mandibular dentition from the Plio/Pleistocene sites of Koobi Fora and Peninj in Kenya, and Olduvai and Laetoli in Tanzania. Initially, it was intended that fossil hominid maxillary roots would also be assessed in this study. However, maxillary teeth complete with roots, either *in situ* or isolated, are poorly represented in comparison to mandibular teeth, and radiographs of the few maxillary specimens proved to be so poor and confusing in detail that this initial intention was abandoned. The specimens included in the fossil hominid sample are listed in Appendix B, and all derive from the palaeontological collections of the National Museums of Kenya and the Tanzanian Government which are presently housed at the Nairobi Museum, Kenya.

Part II

Chapter 5 : Methods

i) Introduction to the radiographic method

ii) The radiographs and exposure factors

iii) Non-metrical observations - premolar root form

iv) The root diagrams

v) Metrical observations

vi) Reliability of measurement technique

vii) Analytical methods

Chapter 5 : Methods

i) Introduction to the radiographic method

In samples such as the ones used in this study - those in which the teeth are *in situ* - the only practicable way to acquire information concerning root size and shape is through radiography. Unfortunately, however, because of the way in which X-rays are produced and emitted, the image on the radiograph is subject to magnification and distortion. As metrical data were to form the basis of this study, and as it was considered necessary to ensure that such data would be as comparable as possible to measurements derived directly from the specimens, ways of reducing the amount of magnification and distortion were investigated.

Four inter-related factors underlie the magnification, distortion and clarity of the radiographic image: the focus-film distance, the object-film distance, the size of the focal spot, and the angulation of the object and film to the X-ray beam (Fitzgerald, 1947; Gron, 1960; McCormack, 1937). However, for each of these variables, certain steps can be taken which reduce the effect of each on the radiographic image.

Because X-rays diverge from their source (the focal spot), the closer the object and film are positioned to the focal spot, the greater will be the magnification of the image (Fig. 3). Increasing the distance between the object and film on the one hand, and the focal spot on the other,

Fig. 3 : Reduced magnification of the radiographic image results from maximum focus-film distance and minimum object-film distance (McCormack, 1937)

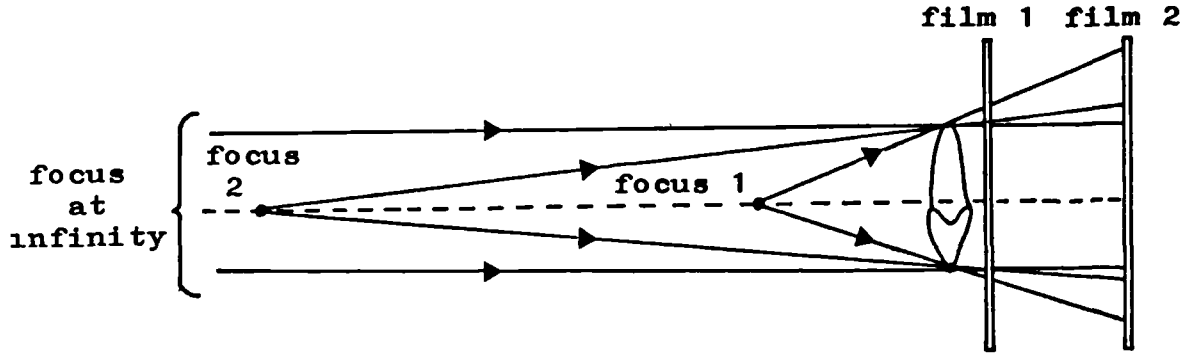
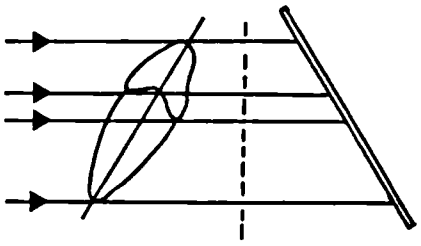
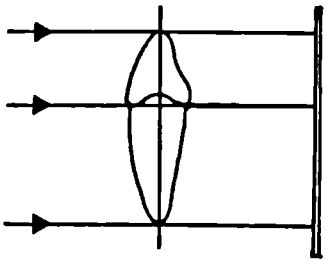


Fig. 4 : The radiographic image produced by a) the 'bisecting-the-angle' technique is unclear and proportionately incorrect, while that produced by b) the parallel-film technique is anatomically accurate (after McCormack, 1937)

a)



b)



results in reduced magnification of the image until, theoretically, with the focal spot positioned at infinity, there is no magnification of the image (McCormack, 1937). For this reason, the use of the maximum practicable focus-film distance will contribute greatly to the production of a minimally, or even indiscernibly, magnified radiographic image. Minimum distances of 20 inches (Fitzgerald, 1947) and of 36 inches (McCormack, 1937) have been suggested as practical focus-film distances which offer the advantages of reduced or negligible image magnification. In this study a focus-film distance of 150 cm was used for all radiographs.

Magnification of the radiographic image can also be minimised by placing the film close to the object (Fig. 3), i.e using a very short object-film distance (McCormack, 1937). However, the supporting bone of the maxillary and mandibular teeth does not usually allow the film to be placed next to the teeth, particularly in the large pongid and fossil hominid specimens. So once again, the advantages of using a long focus-film distance are borne out as the use of such allows much greater latitude in object-film distance. In an experiment illustrating this point Fitzgerald (1947) found that, when using a focus-film distance of eight inches, image magnification was apparent even though the film was in contact with the teeth, while, at a focus-film distance of twenty inches, only a slight degree of magnification was perceptible when the object-film distance was one and a quarter inches. This same study also showed how a long focus-film distance contributes to the clarity of the

radiographic image.

The size of the focal spot also contributes to the degree of magnification and the quality of the radiographic image. As no focal spot is a point source, the X-rays diverging from it create penumbra throughout the radiographic image, and thus magnification and reduced clarity can result (McCormack, 1937). These effects are minimised when the focal spot is small and accentuated when it is large. However, for any given focal spot size, these effects are also minimised if a long-focus film distance is used (McCormack, 1937). For example, when using a focal spot size of a quarter of an inch and an object-film distance of one inch, enlargement of the radiographic image at a focus-film distance of eight inches was five times that produced at a focus-film distance of 36 inches (McCormack, 1937).

In addition, the accuracy of the radiographic image can be further increased by positioning the specimen in the direct path of the 'central ray' (the ray which emanates perpendicularly from the centre of the focal spot).

Factors such as focus-film distance, object-film distance and focal spot size are responsible for the degree of magnification and the clarity of the radiographic image, but another important factor in the production of accurate radiographs is the orientation of the film and object with respect to the X-rays. A technique which has been commonly used in dental radiography is the 'bisecting-the-angle' technique, which was devised in an attempt to accurately

reproduce tooth dimensions on the radiographic film. It requires that the 'central ray' is perpendicular to the plane which bisects the angle between the tooth to be radiographed and the film (Fig. 4). In theory the resulting image accurately reproduces the overall tooth dimensions, but, because certain areas of the tooth are closer to the film than others, and because there is no superimposition of bilateral structures, the resulting image is unclear and distorts the proportions within the tooth. A technique of dental radiography which is very much to be preferred is known as the parallel-film technique (Gron, 1960; McCormack, 1937).

In the parallel-film technique (Fig. 4), the orientation of the film parallel to the object and both perpendicular to the 'central ray' produces a clear radiographic image which is proportionately correct (Barr & Gron, 1959). An important feature of the technique is the use of a long focus-film distance so that the rays may be considered to be parallel in the region of the object and film. According to McCormack (1937), this can be assumed for practical purposes when the focus-film distance is at least 36 inches. The long focus-film distance not only ensures the production of a dimensionally accurate image, but also allows the latitude of object-film distance required to place the film parallel to the object.

In this study, the parallel-film technique was used wherever possible to obtain radiographs of the teeth, but,

owing to the form of certain areas of the mouth, this was not possible for all teeth. In the apes and some fossil hominids, the posterior extent of the mandibular symphysis precludes positioning the film parallel and lateral to the mandibular premolars, particularly the first. And in the majority of specimens, insufficient depth to the palate would have meant that radiographs of the maxillary cheek teeth, obtained using the parallel-film technique, would exclude the apical portions of the roots (Barr & Gron, 1959). Therefore, an alternative procedure was used for these teeth and as this involved angulation of the teeth to the 'central ray' and to the film, it was necessary to use some device for correcting the size of the radiographic image.

A number of methods for correcting image size have been practised in dental radiography (Benkow, 1957; Best et al, 1960; Bramante, 1974; Bregman, 1950; Hamernik, 1957). For the purposes of this study, a different method which utilises a grid formed of squares of known size was considered to be the most appropriate, particularly because of the two-dimensional nature of a grid. This approach to image size correction has been previously proposed by Cave (1929) who used a grid of fine wires embedded in cellophane. In use, the grid is positioned parallel to the long axis of the tooth or teeth and thereby is subject to the same magnification and/or distortion; on the resulting radiograph, the image of the grid is superimposed on those of the teeth. Consequently, the teeth may be angled to the 'central ray' so that a complete tooth image is produced on the radiograph,

but the grid will allow size-correction of the reduced or magnified tooth image. When using a grid, a focus-film distance of at least 36 inches is recommended (Cave, 1929). Although not used as a means of image correction, but rather as a convenient means of measuring image size on the radiograph, Everett and Fixott (1963) designed a grid using enamelled copper wire and Plexiglass. The rigidity and durability offered by their design was considered preferable to the cellophane grid of Cave (1929). In this study, the grid was made of fine copper wire embedded in perspex to form squares of one millimetre, and a slightly thicker gauge was used for every fifth wire so that five millimetre squares were easily distinguishable.

In conclusion, where angulation of the teeth to the 'central ray' was necessary to obtain complete tooth images, the grid was positioned parallel to the long axes of the teeth. The size of the superimposed grid image would thus form a correction factor for the tooth images. This technique was used in obtaining the radiographs of the mandibular premolars and the maxillary cheek teeth.

ii) <u>The radiographs and exposure factors</u>

Depending on the size of film required, either Kodak 'Kodirex' non-screen X-ray film (superseded by Kodak NS-2T non-screen X-ray film) or Kodak Dental Occlusal film were used for the radiographs. All films were processed manually.

For the comparative samples, all exposures were made at 5MA using small focal-spot size. Both KV and exposure time were variable, depending on the degree of penetration required by the individual specimen. The range of kV used was from 60 kV to 100 kV. For the fossil hominid sample, owing to the limitations of the X-ray machine, all exposures had to be made at 25MA and 90 kV, so the only variable was the exposure time.

The following radiographs were taken of each specimen included in the comparative samples. The same radiographs were taken wherever possible for the hominid specimens, depending on the degree of completeness of each.

Mandibular Anterior Tooth Radiograph

Using a focus-film distance of 150 cm, the mandible was positioned with the anterior surface of the symphysis resting on the film and with the longitudinal axis of the incisors parallel to the film. The central ray was directed through the incisors.

Mandibular Premolar Radiographs

Two different protocols were followed in order to obtain radiographs of the mandibular premolars.

In pongid specimens, and in fossil hominid specimens in which both sides of the symphyseal area are preserved, the film cannot be positioned lingual to and parallel with both premolars because of the posterior extent of the mandibular symphysis. For these specimens, the radiograph of the (right) premolars was obtained by angling the premolars to the 'central ray' using the following procedure. Firstly,

the mandible was orientated on the film so that the cervical axis of the (right) premolars was parallel to the film. Then, whilst maintaining the parallel relationship between the cervical axis of the premolars and the film, the (right) mandibular corpus was rotated so that the longitudinal axis of the (right) premolars formed an angulation to the 'central ray'; this angulation being made large enough for the production of complete (right) premolar images on the film, but not so large that the left premolar images would be superimposed on them (Fig. 5). The grid was positioned parallel to the angled plane of the (right) premolars, buccal to the mandibular corpus and as close to it as possible. The 'central ray' was directed through the (right) premolars and a focus-film distance of 150 cm was used. A similar mirror-image radiograph of the left premolars was taken. For the Homo sapiens sample, and for those fossil hominid specimens in which only one side of the symphysis is preserved, the film can be placed lingual and parallel to both premolars, and so the radiographs of these teeth were taken in the same way as for the mandibular molars (Fig. 6).

3. Mandibular Molar Radiographs

Radiographs were obtained for both the right and left molars, those of the right being taken in the following manner. The mandible was clamped into position with the right corpus uppermost and with the mesiodistal plane of the right molars perpendicular to the 'central ray'. The film was positioned inferior to and parallel with this plane and as close to the molars as possible. This was accomplished by placing the

Fig. 5 : Distal view of the orientation for an angled radiograph of the (right) mandibular premolars

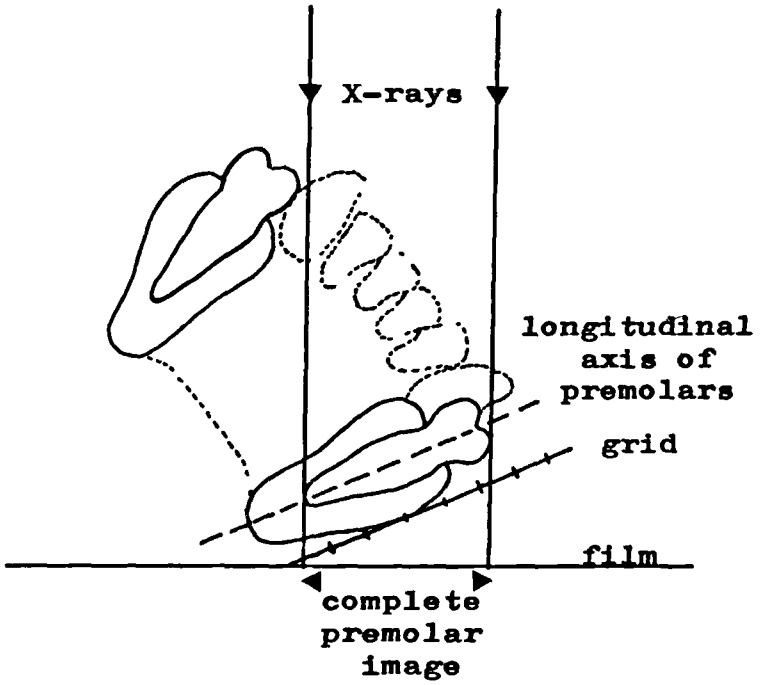
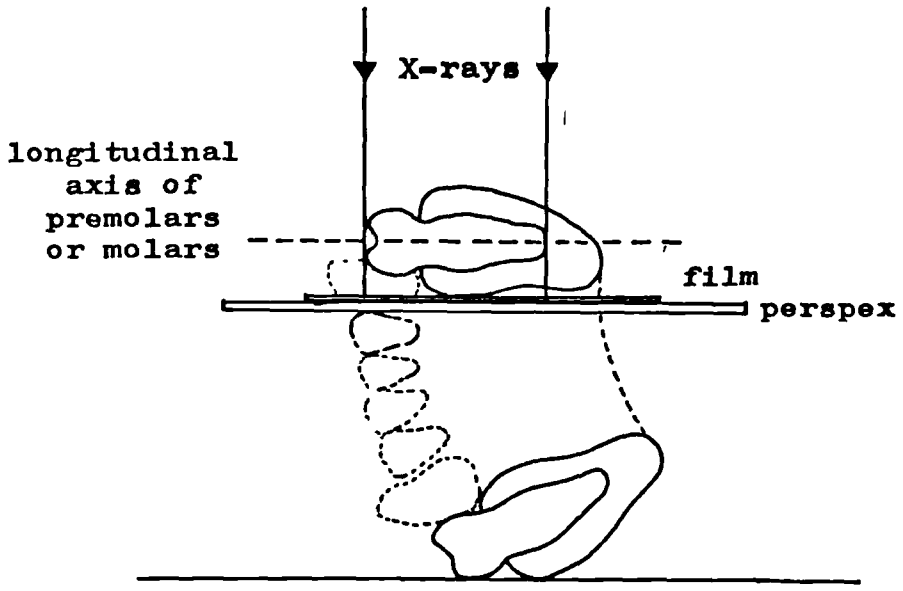


Fig. 6 : Distal view of the orientation for a radiograph of the (right) mandibular premolars or molars, using the parallel-film technique



film on a piece of perspex which had been clamped into position beneath the molars (Fig. 6). The horizontal inclination of the perspex was checked using a spirit level. Resulting from the variability of mandible width, the focus film distance varied slightly for these radiographs, and was generally about 140 cm. For specimens in which the third molar was orientated in a different mesiodistal plane from the $M_{\overline{1}}$ and $M_{\overline{2}}$, or for those in which the images of all three molars would not fit on one film, a separate radiograph of the third molar was taken.

Maxillary Anterior Tooth Radiograph

Using a focus-film distance of 150 cm, the cranium was placed on the film in an inverted position and then orientated so that the longitudinal axis of the incisors was parallel with the film. The 'central ray' was directed through the incisors.

Radiographs of the Maxillary Cheek-Teeth

In the majority of specimens, the depth of the palate does not allow the production of complete tooth images on lateral radiographs; the apical portions of the roots are usually excluded. Therefore, radiographs of the (right) maxillary cheek-teeth were obtained by angling the teeth to the 'central ray' in the following manner.

The cranium was positioned on the film with the palate uppermost and with the cervical axis of the (right) cheek-teeth parallel with the film. While maintaining this parallel relationship, the cranium was rotated so that the longitudinal axis of the (right) cheek-teeth formed an angulation to the central ray; this angulation being great enough to allow the production of complete tooth images on the film, but not so

great that the images of the left cheek-teeth would be superimposed on those of the right (Fig. 7). The grid was positioned superior to the (right) cheek-teeth and as close to them as possible, and orientated so that it was parallel to the longitudinal axis of the lingual roots. The 'central ray' was directed through the (right) first molar, and a focus-film distance of 150 cm was used.

A similar, mirror-image radiograph of the left maxillary cheek-teeth was taken (Fig. 7) except that the grid was positioned inferior to the teeth and parallel with the longitudinal axis of the buccal roots.

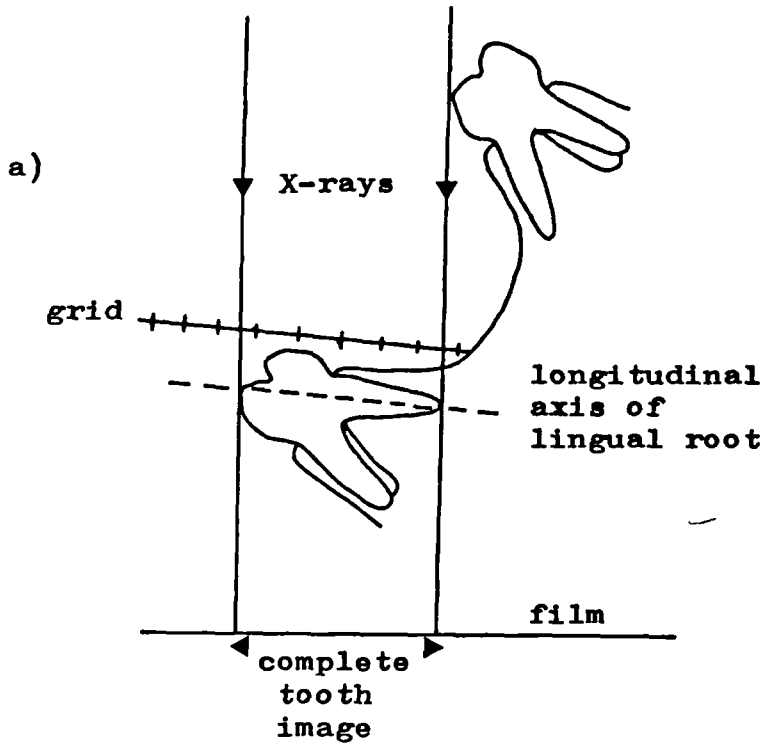
Occolusal Radiographs

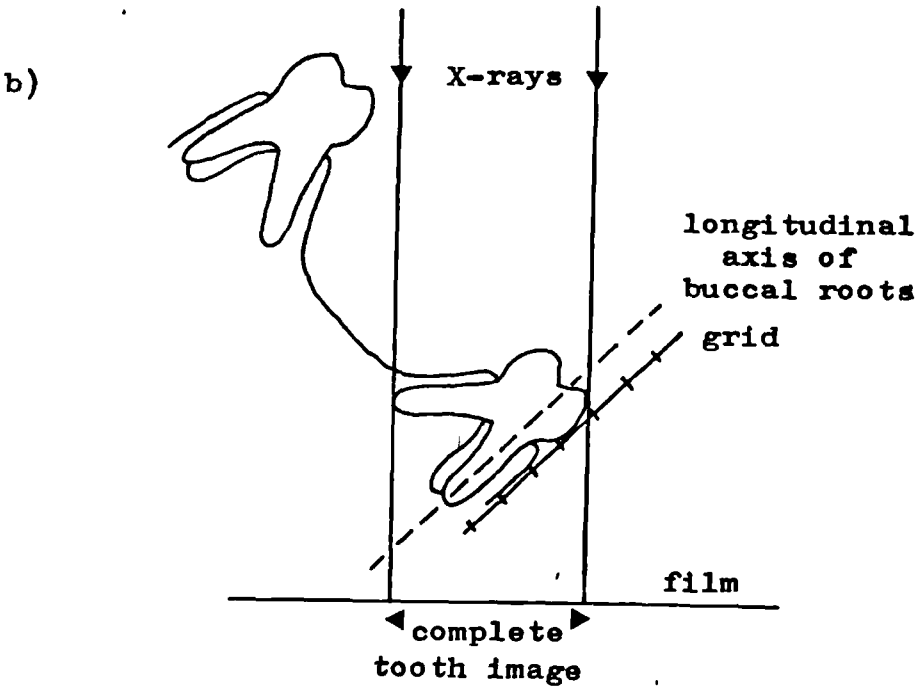
For the occlusal radiograph of the mandibular teeth, the mandible was positioned on the film so that the plane of the cervical lines of the teeth was parallel to the film. For the maxillary teeth, the cranium was orientated with the palate inferiorly and with the plane of the cervical lines of the teeth parallel to the film. Both radiographs were taken using 150 cm focus-film distance.

iii) Non-metrical Observations

Within the samples under consideration in this study, there is both inter- and intra-specific variation in premolar root number and form. For the mandibular premolars, the form of the roots was noted in conjunction with root number, while root number was recorded for the maxillary premolars. The observations of premolar root number and form were taken from the mandibular premolar and maxillary cheek tooth radiographs;

Fig. 7 : Distal view of the orientation for an angled radiograph of a) the right maxillary cheek-teeth and b) the left maxillary cheek-teeth





in addition, reference to the occlusal radiographs often helped in the diagnosis of root form. For some fossil hominids, observations could also be made directly on the specimens where damage or missing crowns have exposed the roots. The observations were made for the antimere, usually the right tooth, that was used to construct the root diagram (described below) and were scored according to the following categories:

Mandibular premolars

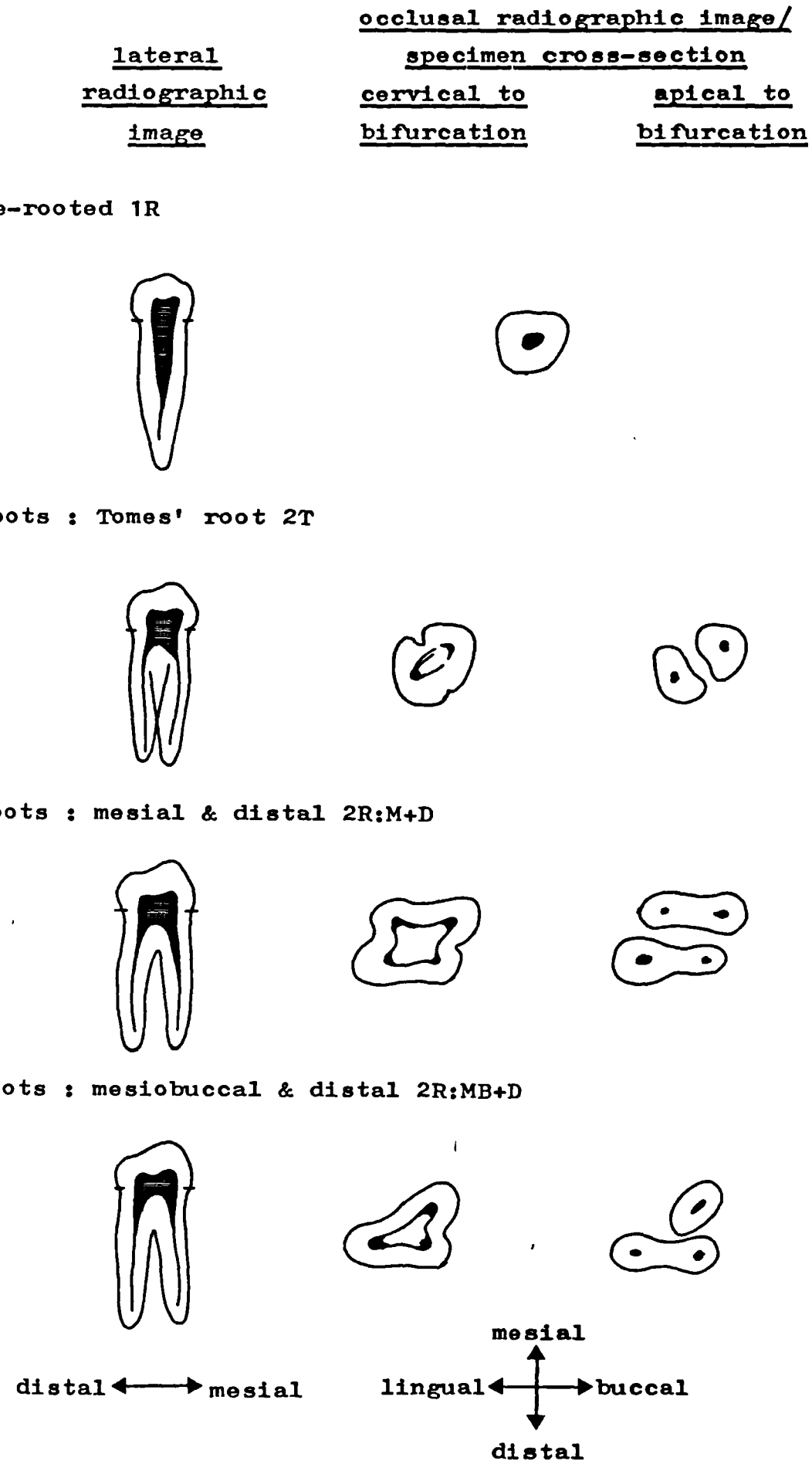
Single root 1R (Fig. 8 a).

The radiographic image shows a single, tapering root with a single (main) root canal. Also included in this category are single roots of Tomes' root form. This root is characterised by the presence of a root groove or cleft on the mesiolingual root surface, and additionally there may also be one on the distobuccal root surface. Such roots were considered to be single where the grooves did not lead to bifurcation, or if they did, where the bifurcation was only in the periapical region. The cross-section of a single root is more or less circular with a centrally placed root canal. If one or both of Tomes' grooves/clefts are present, these indent the mesiolingual and distobuccal margins of the section (the appearance is the same as the section cervical to the bifurcation shown in Fig. 8 b).

Two roots: Tomes' root 2T (Fig.8 b).

In this category were included Tomes' roots in which the characteristic grooves/clefts led to bifurcation. The roots are mesiobuccal and distolingual, and appear superimposed on the radiographic image - the mesial area of the distolingual root overlaps the distal area of the mesiobuccal root. Each

Fig. 8 : Mandibular Premolar Root Form



root has a separate pulp canal. Cervical to the level of bifurcation, the root cross-section shows the mesiolingual and distobuccal clefts, of which the mesiolingual is typically the more developed. Apical to the bifurcation, the oblique mesiolingual to distobuccal bifurcation axis separates the triangular-shaped cross-sections of the two roots.

Two roots: mesial and distal 2R:M+D (Fig.8 c).

The radiographic image shows clear bifurcation into mesial and distal roots, each of which possesses its own pulp canal(s). The buccal and lingual clefts apparent on the root cross-section cervical to the bifurcation lead to the separation of parallel,plate-like mesial and distal roots. Each root commonly possesses two pulp canals.

Two roots: mesiobuccal and distal 2R:MB+D (Fig.8 d).

Although the radiographic image is similar to that for two roots - mesial and distal, the root cross-section is a distinctive shape. Cervical to the bifurcation, the section is triangular, showing greater mesiodistal development buccally. Bifurcation results in a plate-like distal root and a buccolingually constricted mesiobuccal root.

Maxillary Premolars

The maxillary premolars were scored as possessing one, two or three roots. Where three roots were present, i.e. mesiobuccal, distobuccal and lingual roots, there was little difficulty in identifying them on the radiographs. However, in some specimens it was difficult to be certain whether a maxillary premolar had one or two roots because the plane of bifurcation is mesial-distal. If the roots of a two-

rooted maxillary premolar are completely superimposed, then it has very much the same radiographic appearance as a single-rooted premolar. In this study, a maxillary premolar was considered to be two-rooted only if two distinct apices could be discerned; therefore, this criterion has probably led to an under-estimation of two-rooted maxillary premolars.

iv) The root diagrams

Measurements were not taken directly on the radiographs because of the risk of damaging the emulsion and thereby obliterating reference points required for subsequent measurements; instead, the teeth were traced from the radiographs using clear acetate paper and a fine Rotring pen. Tracings were made for all teeth except the maxillary canines; on the maxillary anterior tooth radiographs, the images of the maxillary canines were completely masked by superimposition of the cheek-tooth images. Each tracing was usually made of the right tooth, but where this was missing or damaged, or the radiographic image was unclear, then the tracing was made of the left tooth. (In making the tracings of the hominid teeth, it was found that the definition of many of the fossil hominid radiographs could be considerably improved by viewing them in a darkened room and by masking with black paper all areas of the light box except the pertinent area of the radiograph). For the maxillary incisors and all mandibular teeth, the outline of the root and crown formed the tracing, while for the maxillary cheek-teeth, because of the difficulty of

distinguishing necessary detail in the crown images, only the roots were traced.

The location of the cemento-enamel junction was identified on each tracing. For the incisors, the course of the cemento-enamel junction was traced, while for all other teeth, the mesial and distal locations of the junction were marked. In two-and three-rooted maxillary cheek-teeth, owing to the separation of the buccal and lingual parts of the tooth resulting from the angled radiograph, mesial and distal locations of the cemento-enamel junction were marked separately for the buccal and lingual roots.

The tracings were used to construct root diagrams. This approach has been previously proposed by Kovacs (1966, 1971), who devised a root diagram for quantifying the angulation and curvature of roots. The reference lines used in this study are based in part on those put forward by Kovacs, but they are constructed in relation to the cervical plane, rather than to the occlusal plane as suggested by Kovacs.

For ease of handling and to allow like teeth to be grouped together, the tracings were transferred from the acetate paper to thin, white paper using a light box and a fine Rotring pen. In so doing, the tracings were orientated on the paper with respect to a defined axis - known as the 'cervical axis'. In the case of incisors, the cervical axis passed through the most cervical point of the crown and was perpendicular to the longitudinal axis of the crown. For all other teeth, the cervical axis passed through the mesial and distal locations of the cemento-enamel junction. In the case of two- and three-rooted maxillary cheek-teeth, two separate cervical axes

were marked - one buccally and one lingually.

The following reference points were marked on the root diagrams (Fig 9 and 10). As a result of the variability of root number and form between different tooth-types, they are not all applicable to every tooth-type. The tooth-types for which they are appropriate will be given in brackets after the definition of the reference point.

Point a : the intersection of the cervical axis with the mesial root border (incisors); the most mesial location of the cemento-enamel junction (mandibular premolars and molars, 1R maxillary premolars); the most mesial location of the cemento-enamel junction for the lingual root (2R and 3R maxillary cheek-teeth).

Point a' : the most mesial location of the cemento-enamel junction for the buccal/mesiobuccal root (2R and 3R maxillary cheek-teeth).

Point a'': owing to the location and orientation of the mandibular canine in the dental arcade, its image on the mandibular anterior tooth radiograph is not equivalent to a true mesiodistal projection. Therefore, the point a'' is not the most mesial location of the cemento-enamel junction, but the most medial.

Point b : the intersection of the cervical axis with the distal root border (incisors); the most distal location of the cemento-enamel junction (mandibular premolars and molars, 1R maxillary premolars); the

Fig. 9 : Root diagrams of the mandibular teeth, illustrating the locations of the reference points

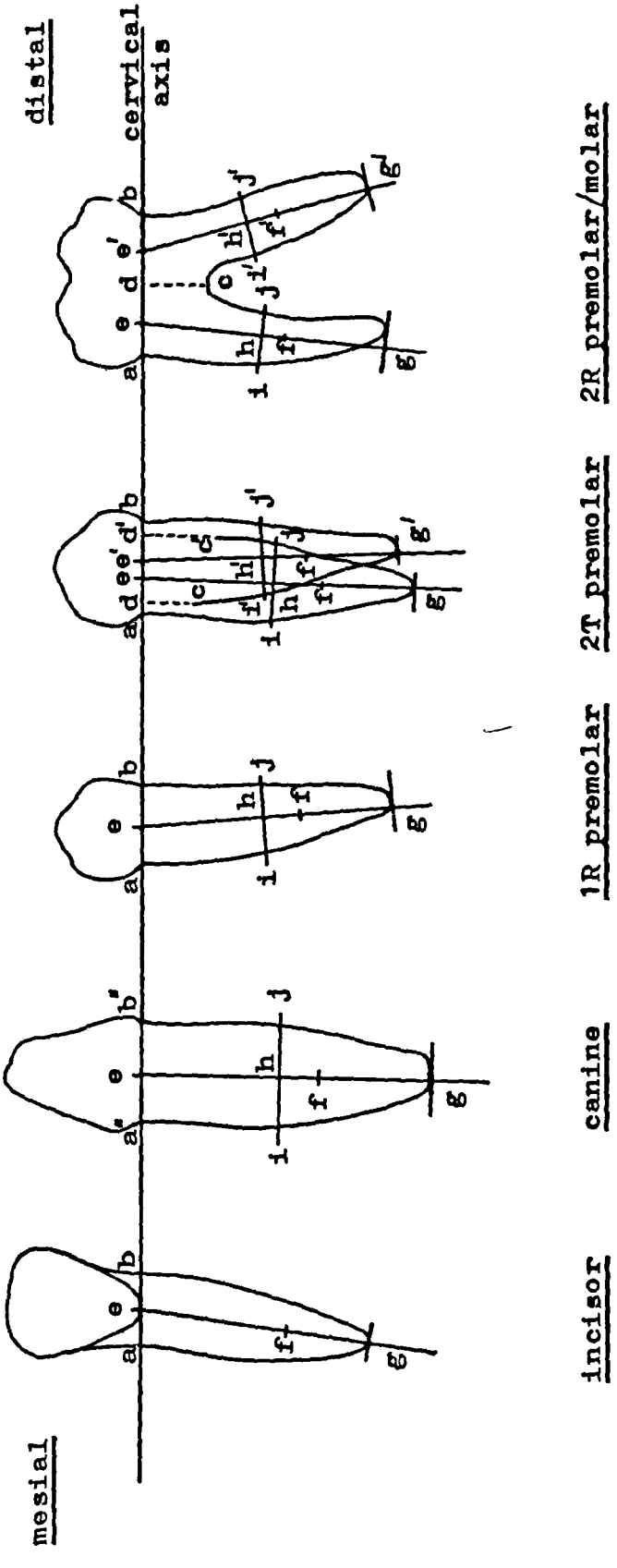
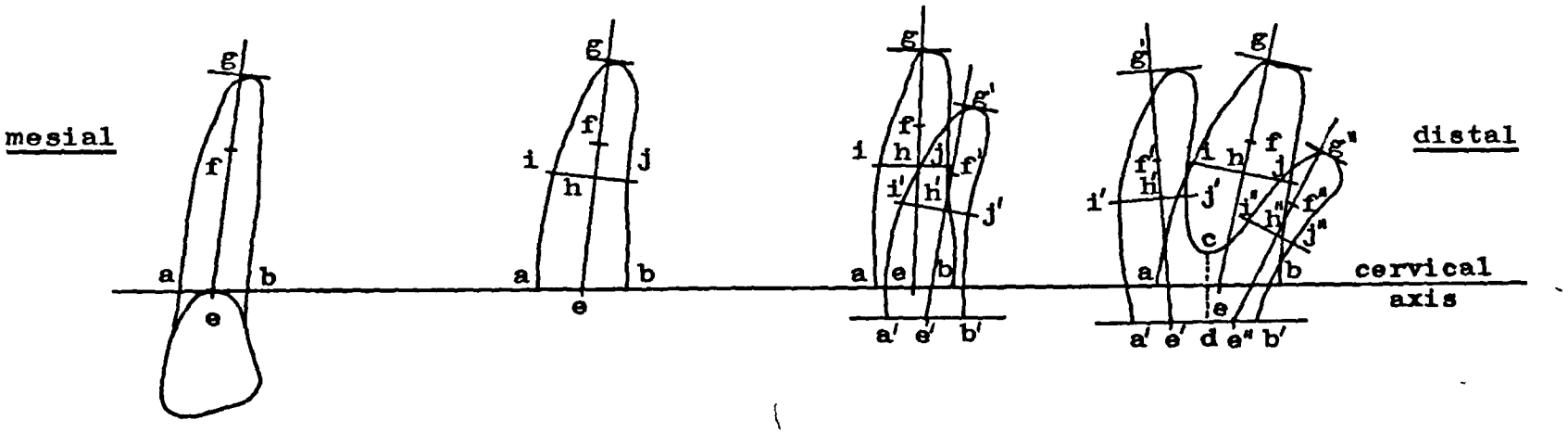


Fig. 10 : Root diagrams of the maxillary teeth, illustrating the locations of the reference points



most distal location of the cemento-enamel junction for the lingual root (2R and 3R maxillary cheek-teeth).

Point b' : the most distal location of the cemento-enamel junction for the buccal/distobuccal root (2R and 3R maxillary cheek-teeth).

Point b'' : the most lateral location of the cemento-enamel junction (mandibular canine).

Point c : the point of bifurcation between the mesial and distal roots (2R mandibular premolars and mandibular molars); the point of bifurcation between the mesiobuccal and distobuccal roots (3R maxillary premolars and maxillary molars); the most cervical point traceable on the mesial border of the disto-lingual root (2T mandibular premolar).

Point c' : the most cervical point traceable on the distal border of the mesiobuccal root (2T mandibular premolar).

Point d : projection of point c onto the cervical axis (2T and 2R mandibular premolars, mandibular molars, 3R maxillary premolars and maxillary molars).

Point d' : projection of point c' onto the cervical axis (2T mandibular premolars).

Point e : the midpoint between point a and point b on the cervical axis (incisors, 1R premolars, 2R and 3R maxillary cheek-teeth); the midpoint between point a'' and point b'' (mandibular canines); the midpoint between point a and point d' (2T mandibular premolars); the midpoint between point a and point d (2R mandibular premolars and mandibular molars).

Point e' : the midpoint between point d and point b (2T and 2R mandibular premolars, mandibular molars); the midpoint between point a' and point b' (2R maxillary premolars); the midpoint between point a' and point d (3R maxillary cheek-teeth).

Point e'' : the midpoint between point d and point b' (3R maxillary cheek-teeth).

Point f : a point on the longitudinal axis of the root which passes through point e and which is distanced about two-thirds of the way from the cervical axis towards the apex (incisors, mandibular canines, 1R premolars, 2T mandibular premolars, mandibular premolars and mandibular molars, 2R and 3R maxillary cheek-teeth).

Point f' : a point on the longitudinal axis of the root which passes through point e' and which is distanced about two-thirds of the way from the cervical axis towards the apex (2T and 2R mandibular premolars, mandibular molars, 2R and 3R maxillary cheek-teeth).

Point f'' : a point on the longitudinal axis of the root which passes through point e'' and which is distanced about two-thirds of the way from the cervical axis towards the apex (3R maxillary cheek-teeth).

Point g : the point of intersection between the longitudinal root axis through point e and a line perpendicular to the root axis which passes through the root apex (all teeth).

Point g' : the point of intersection between the longitudinal root axis through point e' and a line perpendicular

to the root axis which passes through the root apex (2T and 2R mandibular premolars, mandibular molars, 2R and 3R maxillary cheek-teeth).

Point g'' : the point of intersection between the longitudinal axis through point e'' and a line perpendicular to the root axis which passes through the root apex (3R maxillary cheek teeth).

Point h : the midpoint on the longitudinal root axis between point e and point g (all teeth except incisors).

Point h' : the midpoint on the longitudinal root axis between point e' and point g' (2T and 2R mandibular premolars, mandibular molars, 2R and 3R maxillary cheek-teeth).

Point h'' : the midpoint on the longitudinal root axis between point e'' and point g'' (3R maxillary cheek-teeth).

Point i : the point of intersection between the mesial root border and the line through point h which is perpendicular to the longitudinal root axis (all cheek-teeth); the point of intersection between the medial root border and the line through point h which is perpendicular to the longitudinal root axis (mandibular canines).

Point i' : the point of intersection between the mesial root border and the line through point h' which is perpendicular to the longitudinal root axis (2T and 2R mandibular premolars, mandibular molars, 2R and 3R maxillary cheek-teeth).

Point i'' : the point of intersection between the mesial root border and the line through the point h'' which is perpendicular to the longitudinal root axis (3R maxillary cheek-teeth).

Point j : the point of intersection between the distal root border and the line through point h which is perpendicular to the longitudinal root axis (all cheek-teeth); the point of intersection between the lateral root border and the line through point h which is perpendicular to the longitudinal root axis (mandibular canines).

Point j' : the point of intersection between the distal root border and the line through point h' which is perpendicular to the longitudinal root axis (2T and 2R mandibular premolars, mandibular molars, 2R and 3R maxillary cheek-teeth).

Point j'': the point of intersection between the distal root border and the line through point h'' which is perpendicular to the longitudinal root axis (3R maxillary cheek-teeth).

(v) Metrical Observations

The measurements were made using either sliding calipers, or dental calipers in which the points had been ground down to facilitate insertion between the crowns, and were taken to the nearest 0.1 mm. The root measurements were taken directly from the root diagrams. As noted previously, the root diagram was usually made for the right tooth, except where this was missing, damaged, or its radiographic image was unclear, in which case the diagram was made for the left tooth. The crown dimensions, which were measured directly on the specimen, were made for the same antimere used to construct the root diagram. Bilateral jaw dimensions

were also usually made on the right side, except where reference points were missing, when the measurement was made on the left side.

In this study, the policy of taking measurements on one side only was considered advantageous because it allows the inclusion in the samples of specimens for which measurements can only be made on one side. Thus, the samples would be as large as possible and, moreover, there would be direct comparability between the hominid and the comparative data. The lack of significant dental asymmetry in teeth (Garn et al, 1968, 1980; Lundstrom, 1960; Mahler, 1973; Moorrees and Read, 1964; Selmer-Olsen, 1949) suggests that it is justifiable to measure one side only.

Root measurements

The following measurements were taken directly off the root diagrams, and they are mostly defined in terms of the root diagram reference points (Fig 9 and 10). The tooth-types for which the measurements are applicable are given in brackets; a comprehensive list of the measurements, detailing them according to tooth-type, is given in Appendix C.

Neck mesiodistal diameter : the distance along the cervical axis between point a and point b (incisors, mandibular premolars and molars); the distance along the cervical axis between point a" and point b" (mandibular canines). As the radiographic image of the mandibular canine on the mandibular anterior tooth radiograph was not a true mesiodistal projection, canine neck mesiodistal diameter is not exactly equivalent to the neck mesiodistal diameter of the other teeth, but it was measured as it would be consistent between

the samples used in this study. Neck mesiodistal diameter was not measured for the maxillary cheek-teeth because of the separation of the buccal and lingual parts of the crown which resulted from the angled radiographs.

Location of bifurcation : the distance along the cervical axis between point a or a' and point d (2R mandibular premolars, mandibular molars, 3R maxillary cheek teeth). No measurements regarding the bifurcation of 2T mandibular premolars or 2R maxillary premolars, or of the bifurcation between the lingual and buccal roots of a 3R maxillary cheek-tooth, could be made as the axis of bifurcation is not buccolingual.

Height of bifurcation : the distancebetween point c and point d (2R mandibular premolars, mandibular molars, 3R maxillary cheek teeth).

Projected root height : the perpendicular distance between the cervical axis and the root apex (incisors, mandibular and maxillary cheek-teeth).

Actual root height : the distance along the root axis from point e to point g; or from point e' to point g'; or from point e" to point g" (the roots of all teeth).

Root mesiodistal diameter : the distance measured perpendicular to the root axis between point i and point j; or between point i' and point j'; or between point i" and point j" (the roots of all teeth). The mandibular canine dimension is not exactly equivalent to those of the other roots.

Root angulation : the angle measured in degrees between the root axis and the perpendicular to the cervical axis through e/e'/e"/ (incisors, mandibular and maxillary cheek-teeth).

Where root measurements were derived from angled radiographs, i.e. those of the maxillary cheek teeth and those of the mandibular premolars in some specimens, the measurements were corrected using the grid. At a focus-film distance of greater than 36 inches, the X-rays may be assumed to be parallel for all practical purposes (McCormack, 1937), and in this study, a focus-film distance of 150 cm (59 inches) was used for the angled radiographs. For this reason, no correction of mesiodistal root measurements, i.e. neck mesiodistal diameter, location of bifurcation and root mesiodistal diameter, was considered to be necessary since they are accurately reproduced on the radiographic image. However, measurements in the occluso-apical direction - height of bifurcation, projected root height and actual root height - do require correction. This was done by measuring the image size of 20 mm of grid in the occluso-apical direction and correcting the height measurements as follows:

$$\text{Corrected root measurement} = \frac{20 \text{ mm} \times \text{root measurement}}{\text{measured size of 20 mm of grid}}$$

For the maxillary cheek-teeth, the height measurements of the lingual root and of the buccal roots were corrected separately. For lingual roots, the grid correction factor was derived from the radiograph in which the grid had been positioned parallel to the lingual roots, while for buccal roots it was derived from the radiograph in which the grid had been positioned parallel to the buccal roots.

Because the image quality of the hominid radiographs is generally poor, all hominid root measurements were repeated on three separate occasions, and each time the root tracing and root diagram were reconstructed. The average of these values was used to represent the measurement.

Crown Measurements

The following measurements were made directly on the specimens, and were taken for the same antimere as the root measurements.

Crown mesiodistal diameter : the distance between the most mesial point of the crown and the most distal point of the crown, measured parallel with the mesiodistal axis. In the case of cheek-teeth exhibiting interproximal wear, the most mesial and most distal points of the crown were estimated by examining the extent of the interproximal wear and its effect upon the mesial and distal crown borders.

Crown buccolingual diameter : the distance between the most buccal point of the crown and the most lingual point, measured perpendicular to the mesiodistal axis.

Jaw measurements

The jaw measurements were made directly on the specimens, and bilateral measurements were taken on one side only, usually the right. The measurements are based on those used by Riesenfeld and Siegel (1970) and Siegel (1972).

Palatal length : the distance measured in the alveolar plane from prosthion to staphylion.

Palatal breadth : the maximum breadth of the palate, measured perpendicular to the mid-sagittal plane, from outer alveolar border to outer alveolar border.

Mandibular length : the sum of the distance, measured at the alveolar border, from alveolare to the most anterior point on the buccal surface of the canine, and from this latter point to the most distal point of the M_3 crown.

Mandibular depth at the $C_{\overline{1}}$: the distance from the alveolar border, distal to the $C_{\overline{1}}$, to the inferior border of the mandibular body, measured buccally.

Mandibular depth at $M_{\overline{1}}$: the distance from the alveolar border between the roots of $M_{\overline{1}}$ to the inferior border of the mandibular body, measured buccally.

Mandibular depth at $M_{\overline{2}}$: the distance from the alveolar border between the roots of $M_{\overline{2}}$ to the inferior border of the mandibular body, measured buccally.

Mandibular depth at $M_{\overline{3}}$: the distance from the alveolar border between the roots of $M_{\overline{3}}$ to the inferior border of the mandibular body, measured buccally.

(vi) Reliability of measurement technique

For the crown and jaw measurements, the reliability of the measurement technique was assessed by repeating the measurements on one male specimen and one female specimen of each of the comparative samples on five separate occasions. The measurement error was calculated as follows:

$$\% \text{ measurement error} = \frac{(X_1-\bar{X})+(X_2-\bar{X})+(X_3-\bar{X})+(X_4-\bar{X})+(X_5-\bar{X})}{5\bar{X}} \times 100\%$$

where X_1, X_2, X_3, X_4 and X_5 are the five separate values for the measurement, and where $\bar{X}$ is the mean value of these five values.

For each of these specimens, the average percentage measurement error of all the crown and jaw measurements was calculated; this was found to be around 1% or less. In addition, the average measurement error of each measurement was calculated, and several measurements proved to have an error greater than 1%. These were:

$C_{\overline{1}}$ crown mesiodistal diameter	1.1%
$C_{\overline{1}}$ crown buccolingual diameter	1.4%
$P_{\overline{4}}$ crown mesiodistal diameter	1.2%
$I^{1}_{\underline{}}$ crown buccolingual diameter	1.1%
$I^{2}_{\underline{}}$ crown mesiodistal diameter	1.1%
$I^{2}_{\underline{}}$ crown buccolingual diameter	1.2%
$P^{3}_{\underline{}}$ crown mesiodistal diameter	1.1%
Palatal length	1.3%

The average percentage measurement errors mask instances of greater errors recorded for a particular measurement in one sample or another. The following instances of percentage measurement error of 2% or greater were recorded:

Gorilla male	$I_{\overline{1}}$ crown buccolingual diameter	2.2%
Gorilla female	$P_{\overline{4}}$ crown mesiodistal diameter	2.0%
	$I^{2}_{\underline{}}$ crown buccolingual diameter	2.2%
Pan male	$I^{1}_{\underline{}}$ crown buccolingual diameter	2.0%
Pan female	$C_{\overline{1}}$ crown mesiodistal diameter	2.2%
Pongo male	$C_{\overline{1}}$ crown buccolingual diameter	2.1%
Pongo female	$C_{\overline{1}}$ crown mesiodistal diameter	2.1%
	$C_{\overline{1}}$ crown buccolingual diameter	3.6%
	$I^{2}_{\underline{}}$ crown buccolingual diameter	2.6%
H.sapiens male	$P^{3}_{\underline{}}$ crown mesiodistal diameter	2.8%
	Mandibular depth at $M_{\overline{1}}$	3.8%
H.sapiens female	$M^{2}_{\underline{}}$ crown mesiodistal diameter	2.0%

The measurement error of the root measurements was

tested on the hominid sample. This was done because the hominid radiographs are, in general, very much less clear than those of the comparative samples and so, because of greater difficulty in identifying landmarks, may be assumed to show greater measurement error. For the mandibular cheek-teeth, the root tracings were redrawn, the root diagrams reconstructed and the measurements retaken on three separate occasions. The percentage measurement error of each measurement was calculated as follows:

$$\% \text{ measurement error} = \frac{(X_1-\bar{X})+(X_2-\bar{X})+(X_3-\bar{X})}{3\bar{X}} \times 100\%$$

where X_1, X_2 and X_3 are the three separate values for the measurement and where $\bar{X}$ is the mean of these three values.

The average percentage measurement error, taking all root measurements into account, was 4.1%. A greater error than this was associated with certain of the root measurements; the average percentage measurement error of height of bifurcation was 8.6% and that of root mesiodistal diameter was 4.7%. For the former of these two measurements, the greater error was considered to reflect not only the smallness of the dimension being measured, this applying also to root mesiodistal diameter, but also error resulting from estimation of the location of the cervical axis where the crown was missing in damaged specimens.

As an illustration of the increased accuracy afforded through use of the grid in the angled radiographs, in five Gorilla specimens values for measurements of $\underline{P_4}$ obtained from

the angled premolar radiograph were compared with those obtained from the lateral molar radiograph. This comparison was possible in the case of P_4^- as the image of this tooth, usually excluding the area of the mesial root, is included on the lateral molar radiograph. The values obtained for projected root height and actual root height of the distal root and for height of bifurcation were compared between the two radiographs (Table 13). When compared with the values obtained from the molar radiographs, which can be considered to be accurate representations of root size because of the way in which these radiographs were produced, the measured values of the measurements obtained from the premolar radiographs clearly underestimate root size. However, when these measured values are adjusted using the correction factor derived from the grid, very close approximations to the values obtained from the molar radiographs are achieved.

(vii) Analytical methods

The root, crown and jaw data were transferred onto 80 column computer data cards, using sixteen cards per case. The first twelve columns of each data card were used to record card number, taxonomic group, specimen reference number and sex; the remaining 68 columns were used, in four column fields, to record the data. The accuracy of the punched data on the cards was checked, firstly, using an electro-mechanical verifier and, secondly, by listing the data and checking against the original record.

Using the SPSS subprogram Condescriptive (Nie et al,

Table13 Comparison of values obtained for measurements from the angled and lateral radiographs in five Gorilla specimens, illustrating the increased accuracy resulting from use of the grid.

$P_{\overline{4}}$	G1	G2	G3	G4	G5
Projected distal root height					
Measured, molar radiograph	22.1	21.5	20.2	23.3	18.2
Measured, premolar radiograph	16.4	19.9	17.7	20.0	16.8
Corrected, premolar radiograph	22.5	21.6	20.5	23.4	17.8
Actual distal root height					
Measured, molar radiograph	22.4	21.6	20.3	23.6	18.4
Measured, premolar radiograph	17.3	20.1	17.7	20.4	17.0
Corrected, premolar radiograph	23.7	21.9	20.5	23.9	18.0
Height of bifurcation					
Measured, molar radiograph	6.1	5.8	5.4	7.3	4.8
Measured, premolar radiograph	4.6	5.2	4.1	5.9	4.5
Corrected, premolar radiograph	6.3	5.7	4.8	6.9	4.8

1977), for each dimension the mean value, standard error, standard deviation, variance and coefficient of variation were computed for the separate sexes and for the pooled sexes of each comparative sample. For each dimension the statistical significance, based on the two-tailed hypothesis, of the difference in mean values and variances between the sexes of each sample, and between the samples, were computed using the SPSS subprogram T-Test (Nie et al, 1977); where the difference in variance between the sexes or between the samples was statistically significant, the separate variance estimate was used. The SPSS subprograms Condescriptive and T-Test were also used to describe and assess certain indices which were calculated from the dimensions:

$$\text{Location of bifurcation index} = \frac{\text{location of bifurcation}}{\text{neck mesiodistal diameter}} \times 100$$

$$\text{Root robusticity} = \frac{\text{root mesiodistal diameter}}{\text{actual root height}} \times 100$$

$$\text{Height of bifurcation index} = \frac{\text{height of bifurcation}}{\text{projected root height}} \times 100$$

(The projected root height used for this index was whichever was the greater of the mesial and distal roots for the mandibular teeth, and whichever was the greater of the mesiobuccal and distobuccal roots for the maxillary teeth).

Root divergence = mesial/mesiobuccal root angulation - distal/distobuccal root angulation

In each sample, the percentage sexual dimorphism was calculated for each dimension in the following way:

$$\text{percentage sexual dimorphism} = \frac{\text{female } \bar{X}}{\text{male } \bar{X}} \times 100\%$$

The relationship between certain of the dimensions was examined using the SPSS subprogram Scattergram (Nie et al, 1977).

The fossil hominid sample

Owing to the incompleteness of the dimensional data for most of the fossil hominid specimens, these data were not transferred to computer data cards. Computation on the fossil hominid data was executed manually, using a Monroe Model 1930 calculator.

Part III : Results

Chapter 6 : Metrical assessment of the root dimensions in the comparative samples

Chapter 7 : Sexual dimorphism in the root dimensions of the comparative samples

Chapter 8 : The relationship of root height to other root, crown and jaw dimensions in the pongids and *Homo sapiens*

Chapter 9 : Premolar root form in the comparative samples and in the fossil hominid sample

Chapter 10: The root and crown dimensions and indices in the fossil hominid sample

Part III

Chapter 6 : Metrical assessment of the root dimensions in the comparative samples

i) Neck mesiodistal diameter

ii) Location of bifurcation

iii) Root height

iv) Root mesiodistal diameter

v) Height of bifurcation

vi) Root angulation

vii) Summary

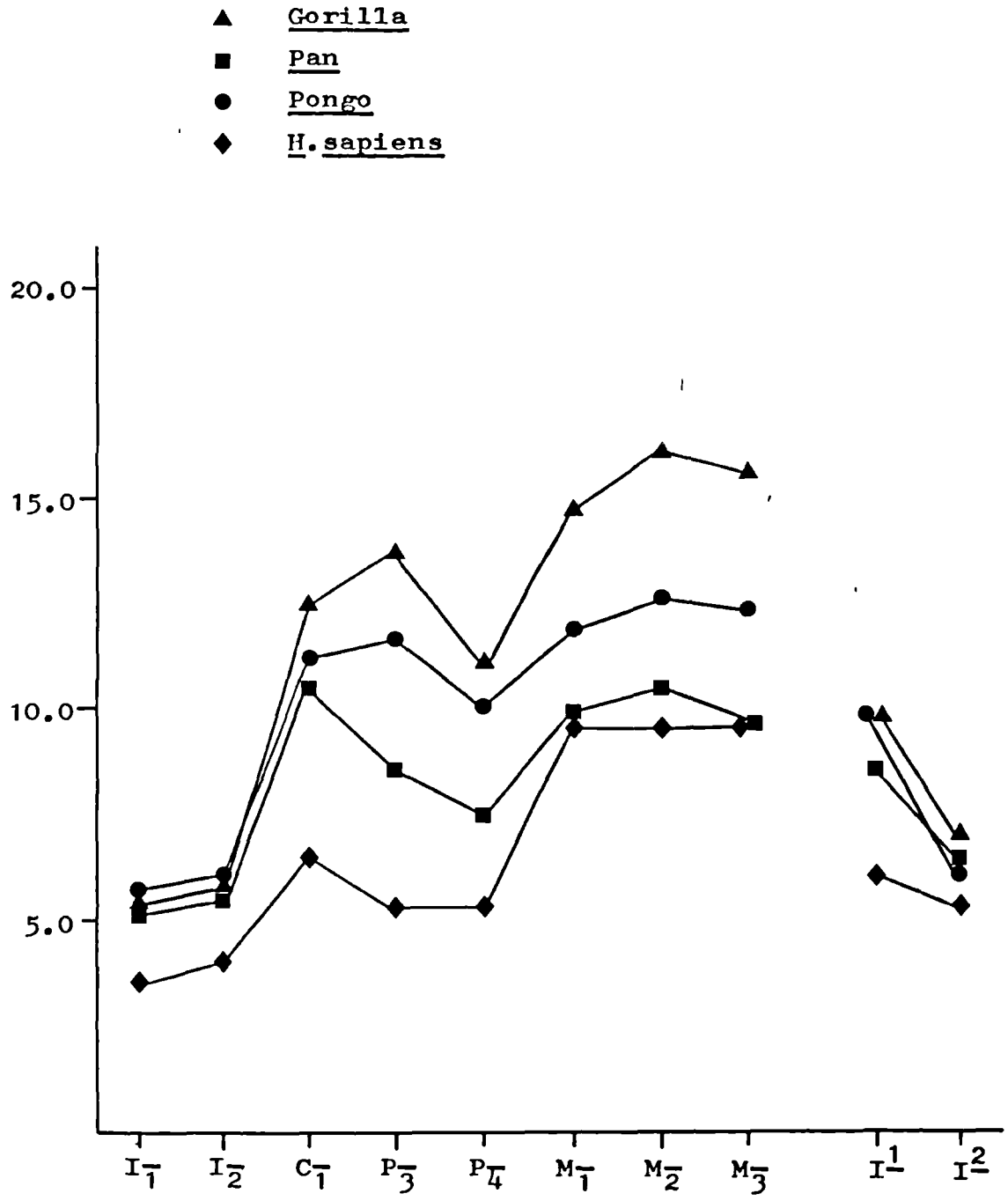
i) Neck mesiodistal diameter

Neck mesiodistal diameter was measured for all mandibular teeth and for the maxillary incisors, but as the radiographic image of the mandibular canine was not a true mesiodistal projection, the measurement is not exactly equivalent to the neck mesiodistal diameters of the other teeth. Statistical summaries for neck mesiodistal diameter in the comparative samples are given in Appendix D (i), and the statistical significance of the differences in mean values and variances between the samples are listed in Appendix F. The mean values for the pongids and the pooled Homo sapiens sample are plotted in Fig 11.

Summary

In the pongids, differences in neck mesiodistal diameter are found in the mandibular postcanine dentition rather than in the anterior dentition. In order of decreasing size, Gorilla has the largest neck mesiodistal diameters for $P_{\overline{3}}$ to $M_{\overline{3}}$, then Pongo and then Pan. Gorilla and Pongo differ most for the neck mesiodistal diameters of the mandibular molars. When both mean values and ranges are taken into account, Pan differs most from the other pongids for the neck mesiodistal diameters of $P_{\overline{4}}$, $M_{\overline{1}}$ and $M_{\overline{3}}$. All the pongids show low intra-specific variation for the neck mesiodistal diameters of $P_{\overline{4}}$ to $M_{\overline{3}}$, thus contributing to the significant differences between them for these teeth. On the other hand, one or more of them show greater variation

Fig. 11 : Mean values of neck mesiodistal diameter in the pongids and Homo sapiens



for the anterior dentition and $P_{\overline{3}}$, and this contributes to similarity between them for these teeth. Canine neck mesiodistal diameter is highly variable in all the pongids, particularly Gorilla.

Apart from the mandibular molar neck mesiodistal diameters which are similar in H.sapiens and Pan, all other H.sapiens neck mesiodistal diameters are smaller than in the pongids. With the exception of the mandibular molars in comparison to Pan, H.sapiens is most similar to the pongids for the lateral incisor neck mesiodistal diameters. This is partly because their mean values differ least for these teeth, but also because these dimensions are highly variable in H.sapiens and, to a lesser extent, in Gorilla and Pongo. The high variability of these teeth in H.sapiens stems from size difference between the Romano-British and Australian Aborigines. In comparison to Gorilla and Pongo, neck mesiodistal diameter is most different in H.sapiens for the premolars, especially $P_{\overline{3}}$, and in comparison to Pan, for the $C_{\overline{1}}$ and $P_{\overline{3}}$. In addition, the central incisor neck mesiodistal diameters differ in H.sapiens and the pongids; not only because the differences in mean values are marked, but also because these dimensions generally show low intra-specific variation so that the H.sapiens and pongid ranges are discontinuous or very nearly so.

Pongids

The neck mesiodistal diameters of the anterior dentition are similar in Gorilla and Pongo, particularly for $I_{\overline{2}}$, $C_{\overline{1}}$ and $I^{\underline{1}}$. Their mean values are significantly different for $I_{\overline{1}}$ ($P < 0.01$) and $I^{\underline{2}}$ ($P < 0.001$), but the differences are small - particularly for $I_{\overline{1}}$ - and their ranges overlap considerably.

All the postcanine neck mesiodistal diameters are smaller in Pongo than in Gorilla ($P < 0.001$). The most marked differences in mean values between them are found in the molars, where their ranges also overlap less than in other teeth. Similarity in the anterior dentition and difference in the molars is contributed to by differences in variation. For P_4 to M_3, Gorilla and Pongo show low intra-specific variation - the values of the coefficient of variation being less than 10.0; but in the anterior dentition and P_3, both generally show higher intra-specific variation - notably I^2 in Gorilla (C.V.=13.5) and especially the C_1 in both, particularly Gorilla (Gorilla C.V.=21.8, Pongo C.V.=15.9).

The neck mesiodistal diameters of the anterior dentition are also similar in Pongo and Pan, being most similar for the lateral incisors and the C_1. Their mean values for the central incisors are significantly different ($P < 0.001$), but particularly for I_1 the difference is small and their ranges overlap considerably. All the mandibular postcanine neck mesiodistal diameters, particularly those of the mandibular premolars, are smaller in Pan than Pongo, their mean values being significantly different ($P < 0.001$). However, Pan shows higher intra-specific variation for P_3 than for P_4 to M_3, as already noted in Pongo, so that their ranges overlap more in P_3 than in P_4 and also than in M_1 and M_3. Pan shows low intra-specific variation for the anterior dentition, with the exception of the canine where high variability (C.V.=16.1) contributes to similarity with Pongo.

The anterior dentition neck mesiodistal diameters are

also similar in Pan and Gorilla, being most similar for the mandibular incisors. Their mean values are significantly different for $I_{\underline{1}}^{1}$ ($P < 0.001$), $I_{\underline{2}}^{2}$ ($P < 0.01$) and the $C_{\overline{1}}$ ($P=0.001$), but their ranges overlap considerably. Both are highly variable for $C_{\overline{1}}$ neck mesiodistal diameter. For $I_{\underline{2}}^{2}$, Gorilla is highly variable and significantly more variable than Pan (F-ratio:P 0.01; Gorilla C.V.=13.5, Pan C.V.=7.7), and the Gorilla range completely overlaps the Pan range. All the mandibular postcanine neck mesiodistal diameters are much smaller in Pan than Gorilla - their mean values being significantly different ($P < 0.001$) - and the low intra-specific variation which they both show for $P_{\overline{4}}$ to $M_{\overline{3}}$ is reflected in the discontinuity of their ranges for $P_{\overline{4}}$, $M_{\overline{1}}$ and $M_{\overline{3}}$. For $P_{\overline{3}}$ and $M_{\overline{2}}$, their ranges are very nearly discontinuous.

Homo sapiens

The mandibular molar neck mesiodistal diameters are similar in Homo sapiens and Pan, particularly for $M_{\overline{1}}$ and $M_{\overline{3}}$. Although the difference in their $M_{\overline{2}}$ mean values is significant ($P < 0.001$), as this dimension is more variable in H.sapiens (F ratio:$P < 0.01$; H.sapiens C.V.=12.5, Pan C.V.= 6.7), the H.sapiens range almost completely overlaps that of Pan. All other neck mesiodistal diameters, particularly those of the $C_{\overline{1}}$ and $P_{\overline{3}}$, are smaller in H.sapiens than Pan, their mean values being significantly different ($P < 0.001$). Of these teeth, similarity between H.sapiens and Pan is most marked for the lateral incisors; partly because their mean values show the smallest difference for $I_{\underline{2}}^{2}$, but also because H.sapiens is highly variable for both lateral incisor neck

mesiodistal diameters ($I_{\overline{2}}$ C.V.=15.2, $I^{\underline{2}}$ C.V.=14.6) so that their ranges overlap more than for other teeth with the exception of the mandibular molars. The H.sapiens and Pan mean values are most different for the $C_{\overline{1}}$ and $P_{\overline{3}}$, and for these dimensions their ranges overlap slightly. However, although their mean values are less different for the central incisors, as both H.sapiens and Pan show low intra-specific variation for $I^{\underline{1}}$ and Pan does for $I_{\overline{1}}$, their ranges are just discontinuous for $I^{\underline{1}}$ and very nearly so for $I_{\overline{1}}$. Overall, H.sapiens shows low intra-specific variation for fewer teeth than does Pan; values for the coefficient of variation are greater than 10.0 for all neck mesiodistal diameters except $M_{\overline{1}}$, $M_{\overline{3}}$ and $I^{\underline{1}}$. However, canine neck mesiodistal diameter is not so variable in H.sapiens (C.V.=13.0) as in Pan (C.V.=16.1).

All neck mesiodistal diameters are smaller in H.sapiens than in Pongo, the differences in their mean values being significant ($P < 0.001$). Their mean values are least different for $I^{\underline{2}}$, and because this dimension is highly variable, particularly in H.sapiens, their ranges overlap more than for any other tooth. Of the remaining teeth, H.sapiens and Pongo are more similar in their mean values and ranges for the mandibular molars and $I_{\overline{2}}$, than they are for the central incisors, canine and particularly the mandibular premolars. Although their mean values are less different for the central incisors than for the canine, as both H.sapiens and Pongo show low intra-specific variation for $I^{\underline{1}}$ and Pongo does for $I_{\overline{1}}$, their ranges are discontinuous for these teeth, but overlap

slightly for canine neck mesiodistal diameter for which Pongo particularly is highly variable. Homo sapiens and Pongo differ most in mean values for the neck mesiodistal diameters of the mandibular premolars, particularly $P_{\overline{3}}$, and their ranges are most discontinuous for these teeth.

The Homo sapiens mean values for neck mesiodistal diameter are all markedly smaller than, and significantly different ($P < 0.001$) from, those of Gorilla. They are most similar in mean values and ranges for the lateral incisor neck mesiodistal diameters, and these dimensions are highly variable, particularly in Homo sapiens. With the exception of $I_{\overline{1}}$, their ranges are discontinuous for all other neck mesiodistal diameters. H.sapiens and Gorilla differ most in mean values and in ranges for the neck mesiodistal diameters of $P_{\overline{4}}$ and especially $P_{\overline{3}}$.

Romano-British & Australian Aborigines

All the measured neck mesiodistal diameters are smaller in the Romano-British than in the Australian Aborigines, the differences in their mean values being significant ($P \leqslant 0.001$ $I_{\overline{1}}$ $I_{\overline{2}}$ $P_{\overline{3}}$ to $M_{\overline{3}}$ $I^{\underline{2}}$; $P < 0.01$ $C_{\overline{1}}$ $I^{\underline{1}}$), but for most teeth the differences are slight. They are most different in mean values for $I_{\overline{1}}$, $I_{\overline{2}}$ and $I^{\underline{2}}$, and for these teeth their ranges overlap less than in other teeth. The high variability of these dimensions in the pooled H.sapiens sample stems mainly from size difference between the Romano-British and Australian Aborigines (C.V.: H.sapiens $I_{\overline{1}}$=13.5, $I_{\overline{2}}$=15.2, $I^{\underline{2}}$=14.6; R-B $I_{\overline{1}}$=7.1, $I_{\overline{2}}$=9.9, $I^{\underline{2}}$=9.1; A.A. $I_{\overline{1}}$=9.0, $I_{\overline{2}}$=11.4, $I^{\underline{2}}$=9.5).

ii) Location of bifurcation

Location of bifurcation was measured for two-rooted mandibular teeth and three-rooted maxillary teeth. It represents the mesiodistal distance along the cervical line from the mesial end to the bifurcation into the mesial and distal roots of the former teeth and the mesiobuccal and distobuccal roots of the latter. In addition, the location of bifurcation index (location of bifurcation/neck mesiodistal diameter x 100) was calculated for the mandibular teeth of the pongids and Homo sapiens in order to investigate the relative mesiodistal placement of the bifurcation. Statistical summaries for location of bifurcation and location of bifurcation index are given in Appendix D(ii) and E(i) respectively, and the statistical significance of the differences in mean values and variances are listed in Appendix F. The mean values for location of bifurcation are plotted out in Fig.12, and those for location of bifurcation index in Fig.13.

Summary

In order of decreasing size, of the pongids the mean values for location of bifurcation are largest in Gorilla, followed by Pongo and then Pan, this being the same pattern seen in the mandibular cheek-teeth for neck mesiodistal diameter. In terms of mean values, maxillary teeth generally show more difference between the pongids than the mandibular teeth; Gorilla and Pongo differ most for $P^{\underline{3}}$, $M^{\underline{2}}$ and $M^{\underline{3}}$, Pongo and Pan for $P_{\overline{4}}$, $P^{\underline{4}}$ and $M^{\underline{1}}$, and Pan and Gorilla for $P^{\underline{3}}$, $P^{\underline{4}}$, $M^{\underline{2}}$ and $M^{\underline{3}}$. However, these are not necessarily the teeth which differ most in range between the pongids, mainly because location of bifurcation is generally highly variable in the maxillary teeth but less variable in the mandibular teeth, particularly the molars. When the pongid ranges are

Fig. 12 : Mean values of location of bifurcation in the pongids and Homo sapiens

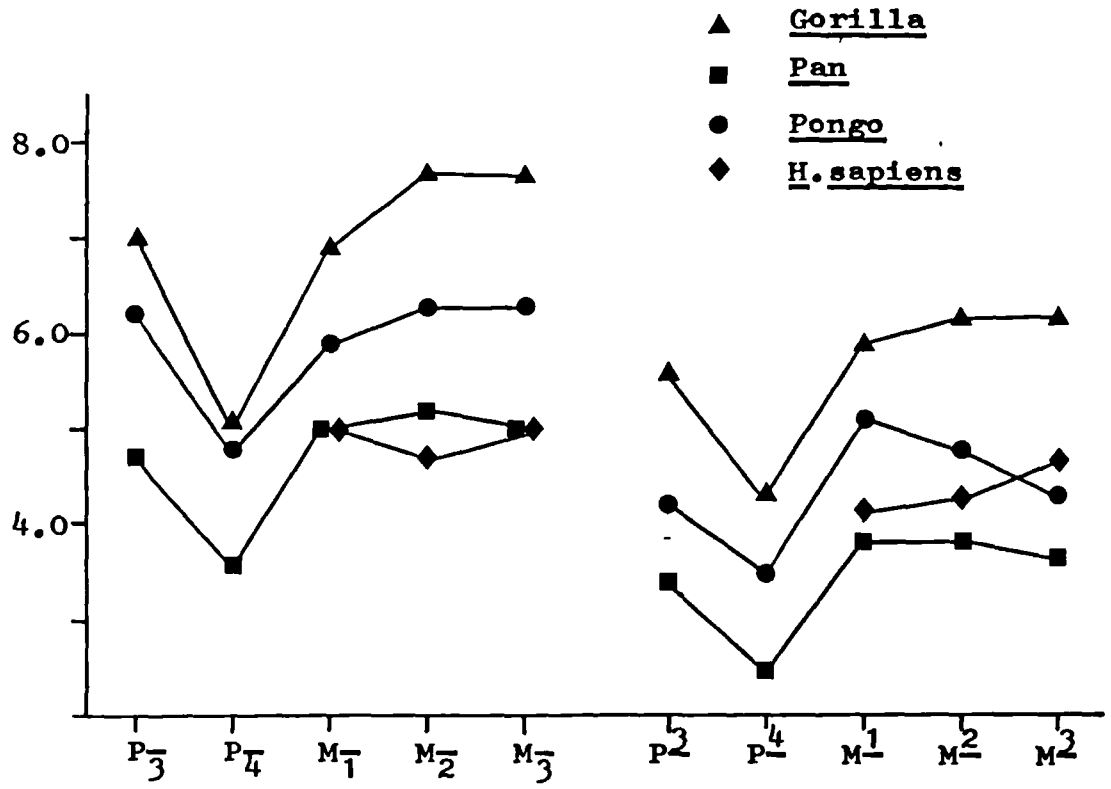
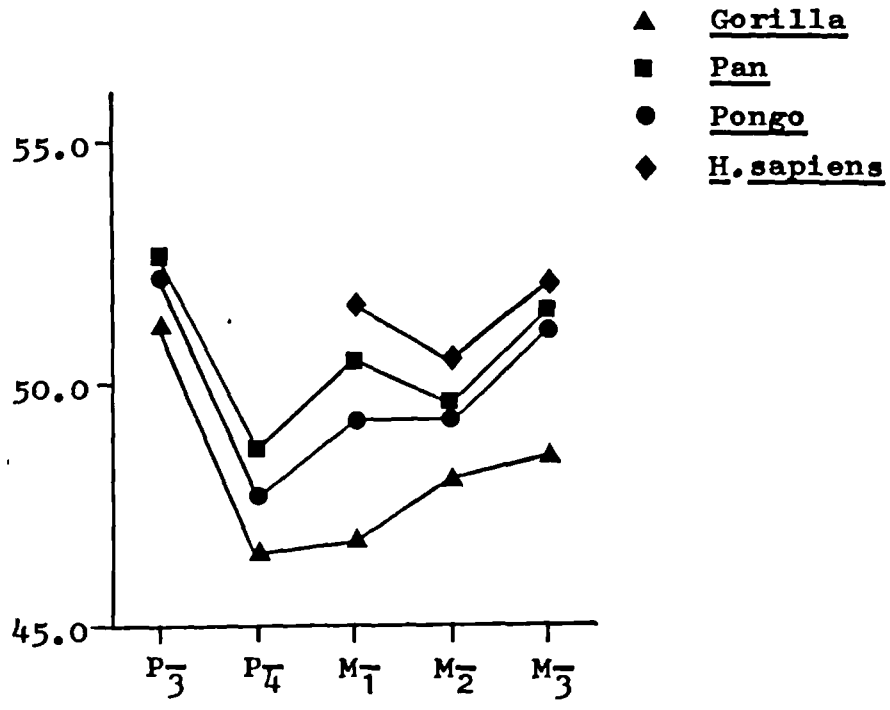


Fig. 13 : Mean values of location of bifurcation index in the mandibular teeth of the pongids and Homo sapiens



examined, Gorilla and Pongo differ most for $M_{\overline{2}}$, $P^{\underline{3}}$ and $M^{\underline{3}}$, Pongo and Pan for $M_{\overline{2}}$ and $M^{\underline{1}}$, and Pan and Gorilla for $M_{\overline{2}}$, $M_{\overline{3}}$ and $M^{\underline{1}}$; thus, the one location of bifurcation which shows maximal difference in range between the pongids is that of $M_{\overline{2}}$.

The molar locations of bifurcation are similar in H.sapiens and Pan, with the exception that the $M^{\underline{3}}$ location of bifurcation is larger in H.sapiens and so this dimension is similar in H.sapiens and Pongo. Otherwise, the smaller values in H.sapiens differ most from those of Pongo for the mandibular molars. All molar locations of bifurcation are smaller in H.sapiens than in Gorilla, and again they differ more in the mandibular molars where their ranges are discontinuous, or very nearly so. The higher variability of location of bifurcation in maxillary teeth than in mandibular teeth contributes to similarity between H.sapiens and the pongids in the former teeth and to difference between them in the latter.

In the pongids, there are no real differences in the relative mesiodistal position of the bifurcation in the mandibular cheek-teeth, nor are there for the mandibular molars when H.sapiens is compared with the pongids. In the pongids and H.sapiens, the relative position of the bifurcation varies little in mandibular two-rooted teeth; all values for the coefficient of variation are less than 10.0.

Pongids

All mean values for location of bifurcation are smaller

in Pongo than Gorilla and significantly different ($P < 0.001$: all except ($P < 0.01$) $P_{\overline{4}}$). However, for the mandibular premolars the difference in their mean values is small and their ranges overlap considerably. Of the remaining teeth, their mean values differ less for the mandibular molars and $M^{\overline{1}}$ than they do for the maxillary premolars and $M^{\overline{2}}$ and $M^{\overline{3}}$, but as location of bifurcation is highly variable in the maxillary cheek teeth (Gorilla $\bar{X}$ C.V.=14.6, Pongo $\bar{X}$ C.V.=17.0), being less variable in the mandibular molars (Gorilla $\bar{X}$ C.V.=10.2, Pongo $\bar{X}$ C.V.= 9.5), their ranges overlap more for $P^{\overline{4}}$, $M^{\overline{1}}$ and $M^{\overline{2}}$ than for the mandibular molars, particularly $M_{\overline{2}}$. Pongo and Gorilla differ most in mean values and ranges for the $P^{\overline{3}}$ and $M^{\overline{3}}$ locations of bifurcation. The relative position of the bifurcation in the mandibular cheek-teeth is similar in Gorilla and Pongo, particularly so for $P_{\overline{3}}$, $P_{\overline{4}}$ and $M_{\overline{2}}$. The Gorilla and Pongo mean values for the location of bifurcation index are significantly different for $M_{\overline{1}}$ ($P < 0.001$) and $M_{\overline{3}}$ ($P < 0.01$), but the differences are small and their ranges overlap considerably.

The locations of bifurcation are smaller in Pan than in Pongo; their mean values are significantly different ($P < 0.001$) with the exception of $P^{\overline{4}}$, but the Pan sample for $3RP^{\overline{4}}$ is very small. The Pan and Pongo mean values differ most for $P_{\overline{3}}$ and $P_{\overline{4}}$, and $P^{\overline{4}}$ and $M^{\overline{1}}$. Of the mandibular teeth, they are more variable for the $P_{\overline{3}}$ and $P_{\overline{4}}$ locations of bifurcation than they are for the $M_{\overline{2}}$ location of bifurcation, and even though their mean values differ less for $M_{\overline{2}}$ their ranges for this tooth overlap less than their ranges for the mandibular premolars.

Most maxillary locations of bifurcation, particularly that of $P^{\underline{4}}$, are highly variable in Pongo ($\bar{X}$ C.V.=17.0) and Pan ($\bar{X}$ C.V.=17.5), but they are less variable for $M^{\underline{1}}$ (Pongo C.V.=12.4, Pan C.V.-10.6) and their ranges overlap least for this location of bifurcation. The relative position of the bifurcation in the mandibular cheek teeth is similar in Pongo and Pan.

All locations of bifurcation are much smaller in Pan than in Gorilla. Their mean values are all significantly different ($P < 0.001$), and are most similar for $P_{\underline{4}}$ and $M_{\underline{1}}$ and most different for $P^{\underline{4}}$ and $M^{\underline{3}}$. The Gorilla and Pan mean values differ more for the maxillary locations of bifurcation than for any of the mandibular ones. However, location of bifurcation is generally highly variable in the maxillary teeth and less variable in the mandibular, and the Pan and Gorilla ranges differ more in $M_{\underline{2}}$ - where they are discontinuous - than in any of the maxillary teeth - where they overlap slightly. The relative position of the bifurcation is similar in Pan and Gorilla for all the mandibular cheek teeth, particularly for $P_{\underline{3}}$, $P_{\underline{4}}$ and $M_{\underline{2}}$. The mean values for the location of bifurcation index are significantly different for $M_{\underline{1}}$ ($P < 0.001$) and $M_{\underline{3}}$ ($P < 0.01$), but the differences are small and their ranges overlap considerably.

Homo sapiens

With the exception of the $M^{\underline{3}}$ location of bifurcation, the molar locations of bifurcation are similar in H.sapiens and Pan, particularly for $M_{\underline{1}}$ and $M_{\underline{3}}$. For $M_{\underline{2}}$, the larger Pan

mean value is significantly different ($P < 0.01$) from the H.sapiens mean value, but the H.sapiens range completely overlaps the Pan range and this dimension is more variable in H.sapiens (H.sapiens C.V.=12.7, Pan C.V.=7.9). From $M_{\overline{1}}^{1}$ to $M_{\overline{3}}^{3}$, the H.sapiens mean values become increasingly larger than those of Pan, and the differences in their mean values are significant ($P=0.001$ $M_{\overline{2}}^{2}$, P 0.01 $M_{\overline{1}}^{1}$ $M_{\overline{3}}^{3}$). However, for $M_{\overline{1}}^{1}$ and $M_{\overline{2}}^{2}$ their ranges overlap very considerably reflecting the high variation in one or other of them (H.sapiens $M_{\overline{1}}^{1}$ C.V.=14.6, $M_{\overline{2}}^{2}$ C.V.=11.6; Pan $M_{\overline{1}}^{1}$ C.V.=10.6, $M_{\overline{2}}^{2}$ C.V.=15.6). Their ranges overlap least for $M_{\overline{3}}^{3}$, even though both are highly variable for this dimension (H.sapiens C.V.=23.4, Pan C.V.=15.6). The relative position of the bifurcation in the mandibular molars is similar in H.sapiens and Pan.

With the exception of the $M_{\overline{3}}^{3}$ location of bifurcation, all other molar locations of bifurcation are smaller in H.sapiens than in Pongo, the mean values being significantly different ($P < 0.001$ $M_{\overline{1}}$ $M_{\overline{2}}$ $M_{\overline{3}}$ $M_{\overline{1}}^{1}$; $P < 0.01$ $M_{\overline{2}}^{2}$). Their mean values are most different and their ranges overlap least for the mandibular molars. From $M_{\overline{1}}^{1}$ to $M_{\overline{3}}^{3}$, their mean values become increasingly similar and their ranges overlap more. The $M_{\overline{3}}^{3}$ location of bifurcation is similar in H.sapiens and Pongo; the difference in their mean values is not significant and the H.sapiens range completely overlaps the Pongo range as H.sapiens is particularly highly variable for this dimension (H.sapiens C.V.=23.4, Pongo C.V.=16.4). The relative position of the bifurcation is similar in H.sapiens and Pongo for the mandibular molars; their $M_{\overline{1}}$ mean values for the location of bifurcation index are significantly different ($P < 0.01$), but

the difference is small and their M_1 ranges overlap considerably.

All molar locations of bifurcation are much smaller in H.sapiens than in Gorilla, and their mean values are all significantly different ($P < 0.001$). The H.sapiens and Gorilla mean values are most different for M_2 and M_3, but for all the mandibular molars their ranges show less overlap - being either discontinuous (M_2) or very nearly so (M_1 M_3) - than they do for the maxillary molars. Location of bifurcation is less variable in the mandibular than in the maxillary molars. The relative position of the bifurcation is similar in H.sapiens and Gorilla for the mandibular molars; the mean values for location of bifurcation index are significantly different ($P < 0.001$ M_1; $P < 0.01$ M_2 M_3), but the differences are small and their ranges overlap considerably.

Romano-British & Australian Aborigines

The mean values of location of bifurcation differ most in the Romano-British and Australian Aborigines for the third molars; however, while the M_3 mean values are significantl different ($P < 0.001$), the difference in M^3 mean values was not tested for significance because the M^3 sample is small in the Romano-British. The mean values for other molars are significantly different ($P < 0.001$ M_2; $P < 0.01$ M_1 M^1), but the differences are small and their ranges overlap considerably.

iii) Root height

The following assessment of root height is based on the

dimension 'actual root height', which is the height of the root measured along the root axis. This dimension was measured for all roots except the maxillary canine root (for reasons previously explained, Chapter 5), but as the mandibular canine radiographic image was not a true mesiodistal projection, its actual root height is not exactly equivalent to other actual root heights, though it is probably a very close approximation. Projected root height - the perpendicular distance from the cervical line to the apex - was measured for all roots except both canine roots. Statistical summaries for actual root height and projected root height in the comparative samples are given in Appendices D(iii) and D(iv) respectively, and the statistical significance of the differences in mean values and variances between the samples are listed in Appendix F. The mean values of actual root height in the pongids and the pooled Homo sapiens sample are plotted out in Figs. 14 and 15.

Summary

Root height is very similar in Gorilla and Pongo, but shorter in Pan - particularly for some mandibular molar roots and some maxillary lingual roots. Pan is most similar to the other pongids for the maxillary incisor, mandibular canine and $P_{\overline{4}}$ mesial root heights. Root height is generally highly variable, being particularly so in all three pongids for the $M_{\overline{3}}$ distal root and the maxillary buccal roots, and in Pan and Pongo for canine root height. The high variability of these dimensions may contribute to similarity in root height between the pongids.

Fig. 14 : Mean values of mandibular actual root height in the pongids and Homo sapiens

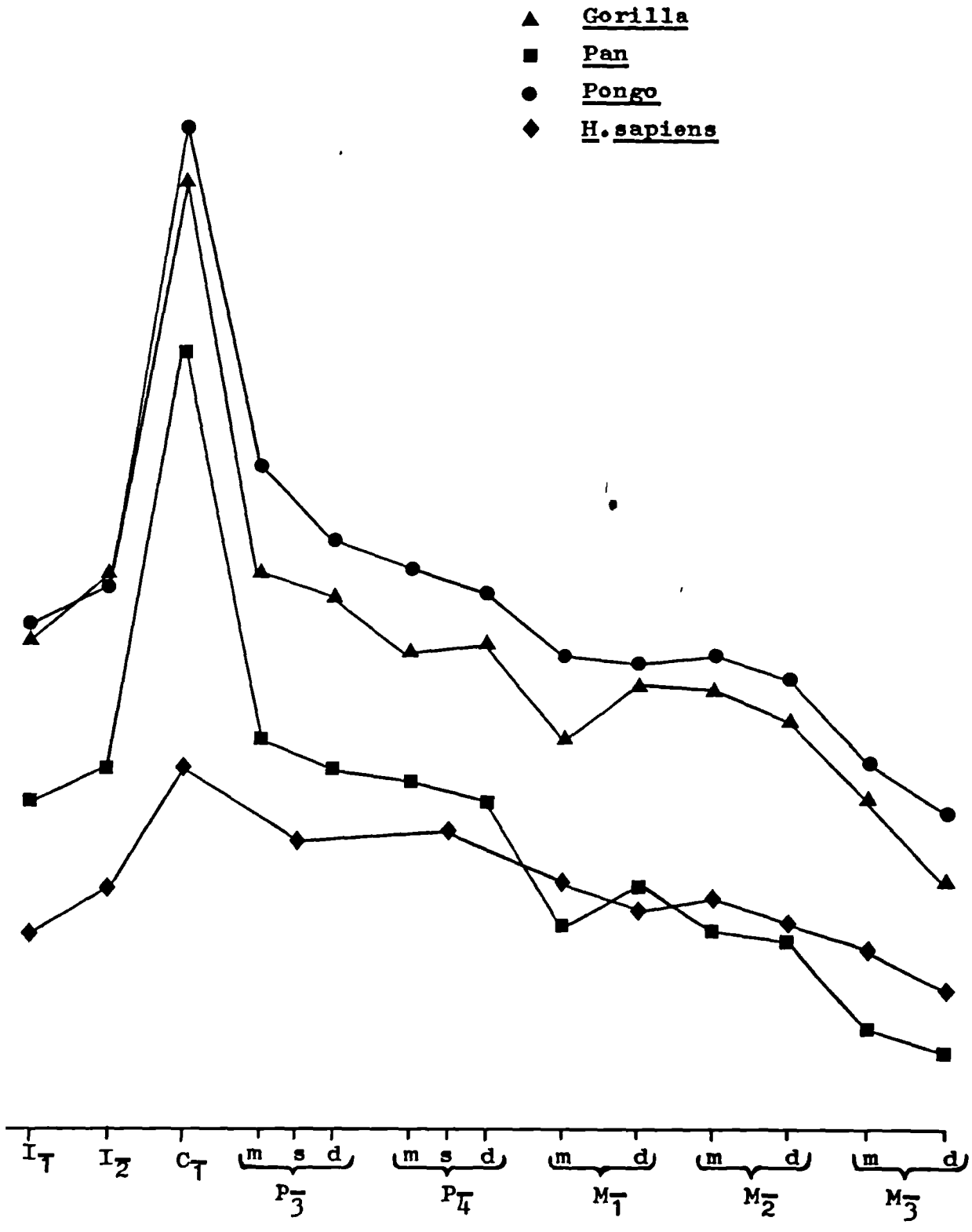
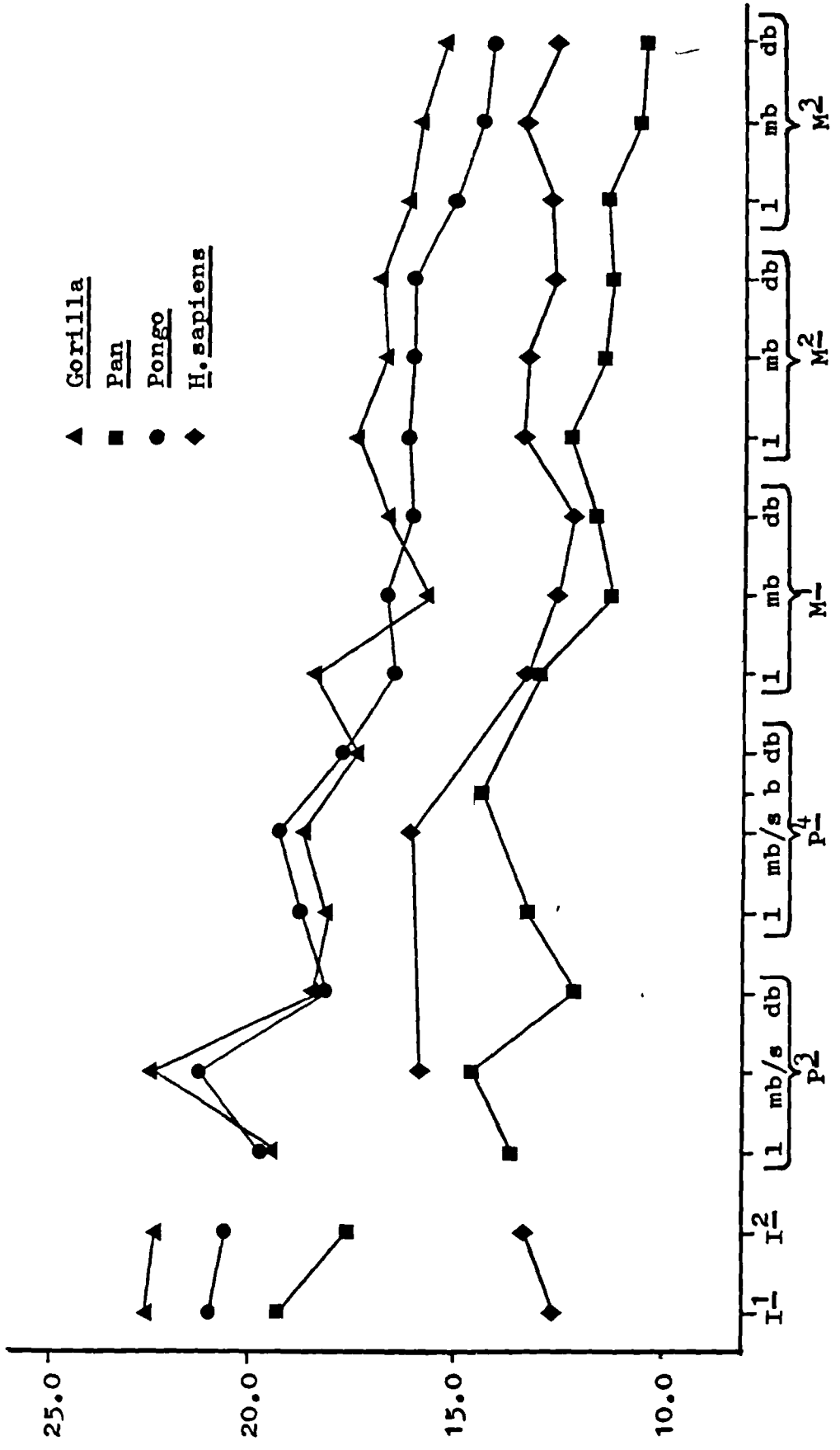


Fig. 15 : Mean values of maxillary actual root height in the pongids and Homo sapiens



Some third molar roots are longer in H.sapiens than in Pan - otherwise they are similar for molar root height, but H.sapiens has much shorter roots than Pan for the anterior dentition especially the $I^{\underline{1}}$ and $C_{\overline{1}}$ roots. With the exception of the $M^{\underline{3}}$ buccal roots, all H.sapiens roots - particularly the anterior roots - are shorter than those of Pongo and Gorilla. For the anterior roots with the exception of $I^{\underline{2}}$, the H.sapiens ranges are discontinuous or very nearly so with the Pongo and Gorilla ranges. H.sapiens is also generally highly variable for root height, being particularly so for the $C_{\overline{1}}$ and $M^{\underline{3}}$ roots in common with some or all of the pongids. Size difference between the Romano-British and Australian Aborigines partly underlies the high variability noted for some, but not all, root heights in the pooled H.sapiens sample.

Pongids

Root height is very similar in Gorilla and Pongo; although a few mean values are significantly different ($P \ll 0.001$ $P_{\overline{3}}$m $M_{\overline{1}}$m $M^{\underline{1}}$1; $P < 0.01$ $P_{\overline{4}}$m), the differences are small and their ranges overlap considerably. Similarity between them is accentuated by the general high variability of root height (Gorilla $\bar{X}$ C.V.=14.3, Pongo $\bar{X}$ C.V.=15.1). Both are particularly highly variable for the $M_{\overline{3}}$ distal root (Gorilla C.V.=15.9, Pongo C.V.=18.4) and for the maxillary buccal roots (Gorilla $\bar{X}$ C.V.=18.0, Pongo $\bar{X}$ C.V.=16.1). In addition, Pongo is particularly highly variable for the root heights of the $C_{\overline{1}}$, the $P_{\overline{3}}$ distal, $P_{\overline{4}}$ and $M_{\overline{2}}$ roots, and the $M^{\underline{2}}$ and $M^{\underline{3}}$ lingual roots, while Gorilla is for the $P^{\underline{3}}$ lingual root. For some root heights, Pongo is more variable than Gorilla: for the $C_{\overline{1}}$ (Gorilla C.V.=12.5, Pongo C.V.=19.4), the roots of $P_{\overline{4}}$ - which

vary little in Gorilla (F ratio:$P < 0.001$ $P_{\overline{4}}m$, $P_{\overline{4}}d$; Gorilla $P_{\overline{4}}m$ C.V.-9.7, $P_{\overline{4}}d$ C.V.=9.0; Pongo $P_{\overline{4}}m$ C.V.=15.9, $P_{\overline{4}}d$ C.V.= 15.1), and the $M^{\overline{2}}$ lingual root (Gorilla C.V.=10.5, Pongo C.V.=16.4).

All roots are shorter in Pan than in the other pongids; all Pan mean values are significantly different from those of Gorilla and Pongo ($P \leqslant 0.001$ Pan/Gorilla all roots, Pan/Pongo all roots except ($P < 0.01$) $I^{\overline{1}}$). In common with the other pongids, root height in Pan is generally highly variable (all roots $\bar{X}$ C.V.=13.6), particularly for the $M_{\overline{3}}$ distal root (C.V.=14.7) and the maxillary buccal roots ($\bar{X}$ C.V.=16.2). In common with Pongo, $C_{\overline{1}}$ root height is also particularly highly variable (C.V.=16.2). Pan is most similar to the other pongids for the root heights of $I^{\overline{1}}$ and $I^{\overline{2}}$, the $C_{\overline{1}}$ and the $P_{\overline{4}}$ mesial root; for these roots there is considerable overlap between the Pan and the other pongid ranges. Particularly high variability in one or both of Pan and Pongo contributes to the similarity between Pan and the other pongids for the $C_{\overline{1}}$ and $P_{\overline{4}}$ mesial root heights. Pan differs most from the other pongids in mandibular molar root heights, and to a lesser extent in maxillary lingual root heights. In comparison to Gorilla and Pongo, Pan mean values differ most for the $M_{\overline{3}}$ mesial root, and for this root the Pan range is very nearly discontinuous with those of the other pongids. The Pan ranges are also very nearly discontinuous for the $M_{\overline{1}}$ and $M_{\overline{2}}$ mesial roots and the $P^{\overline{3}}$ lingual root in comparison to Pongo, and for the $M_{\overline{1}}$ distal, $M_{\overline{2}}$ mesial and the $M^{\overline{2}}$ and $M^{\overline{3}}$ lingual roots in comparison to Gorilla. Other roots - notably maxillary

buccal roots - may show greater difference in mean values between Pan and the other pongids, but these root heights are particularly highly variable and there is more overlap of their ranges.

Homo sapiens

Root height is generally highly variable in H.sapiens (all roots $\bar{X}$ C.V.=13.8) as in the pongids, being so particularly for the roots of the C_1 (C.V.=16.4), I^2 (C.V.=16.8), P^3 (C.V.=17.5), and P^4 (C.V.=15.7), and the roots of M^3 ($M^3$1 C.V.=15.2, M^3mb C.V.=20.9, M^3db C.V.=18.7). However, the buccal root heights of M^1 and M^2 are not as variable in H.sapiens as in the pongids.

Molar root height is similar in H.sapiens and Pan, particularly for the M_1 distal and M^1 distobuccal roots, the M_2 roots and the maxillary molar lingual roots. Their mean values are significantly different for the other molar roots ($P \leqslant 0.001$ M_3m M_3d M^1mb M^2mb M^3db; $P < 0.01$ M_1m M^2db M^3db), but for most of these the H.sapiens mean values are only slightly larger than those of Pan and their ranges overlap considerably. In the molars, their mean values differ most for the M_3 mesial and M^3 buccal roots and their ranges for these roots overlap less than in other molar roots, even though both are highly variable for the M^3 buccal roots. The H.sapiens and Pan mean values for the root height of $1RP_3$ were not significantly different. For all anterior roots, the smaller H.sapiens mean values are significantly different ($P < 0.001$) from those of Pan. The C_1 and I^1 roots are much shorter in H.sapiens than in Pan; of all roots, their mean

values differ most and their ranges show least overlap for these roots. However, for the lateral incisor roots, the Pan and H.sapiens ranges overlap considerably; for $I^{\underline{2}}$, the H.sapiens range almost completely overlaps the Pan range resulting from the high variability of this dimension in H.sapiens (C.V.=16.8).

With the exception of the $M^{\underline{3}}$ buccal roots, all roots are shorter in H.sapiens than in Pongo, their mean values being significantly different ($P < 0.001$: all roots except ($P < 0.01$) $M^{\underline{3}}1$). Their mean values are most similar for the maxillary molar roots. Pongo is highly variable for most maxillary roots and the H.sapiens ranges for all maxillary molar roots except the $M^{\underline{1}}$ buccal roots are considerably or completely overlapped by those of Pongo. H.sapiens and Pongo differ more for mandibular molar roots, but most of all for anterior roots. All anterior roots, particularly the $C_{\overline{1}}$ root, are much shorter in H.sapiens than in Pongo, and their ranges are very nearly discontinuous for all except the $I^{\underline{2}}$ root for which H.sapiens particularly is highly variable.

Again, with the exception of the $M^{\underline{3}}$ buccal roots, all roots are much shorter in H.sapiens than in Gorilla, their mean values being significantly different ($P < 0.001$). Their mean values differ least for the $M^{\underline{3}}$ buccal and $M_{\overline{3}}$ distal root heights and their ranges for these dimensions, particularly for the $M^{\underline{3}}$ buccal roots, overlap considerably. Of the molar roots, H.sapiens and Gorilla differ most in mean values and ranges for the $M_{\overline{1}}$ distal and $M_{\overline{2}}$ roots, and the $M^{\underline{1}}$ and $M^{\underline{2}}$

lingual roots. However, root height in H.sapiens and Gorilla differs most in the anterior roots. Their ranges are discontinuous, or very nearly so, for all anterior root heights except that of $I^{\underline{2}}$ as H.sapiens is highly variable for this dimension.

Romano-British and Australian Aborigines

Some roots are shorter in the Romano-British than in the Australian Aborigines, their mean values being significantl different ($P \leqslant 0.001$ $C_{\underline{1}}$ $P^{\underline{3}}$ $P^{\underline{4}}$ $M^{\underline{2}}$mb; $P < 0.01$ $P_{\underline{3}}$ $M_{\underline{2}}$m $M_{\underline{2}}$d $I^{\underline{2}}$ $M^{\underline{2}}$db). The Romano-British mean values differ most from those of the Australian Aborigines for the $I^{\underline{2}}$, $C_{\underline{1}}$, $P^{\underline{3}}$ and $P^{\underline{4}}$ roots - roots which are all highly variable in the pooled sample. The size difference between the two sub-samples partly underlies the high variability of the $C_{\underline{1}}$ $P^{\underline{3}}$ and $P^{\underline{4}}$ root heights in the pooled sample (C.V. H.sapiens (pooled) $C_{\underline{1}}$=16.2, $P^{\underline{3}}$=17.5, $P^{\underline{4}}$=15.7; R-B $C_{\underline{1}}$=11.9, $P^{\underline{3}}$=13.0, $P^{\underline{4}}$=12.3; A.A. $C_{\underline{1}}$=15.7, $P^{\underline{3}}$=13.8, $P^{\underline{4}}$=14.0), though the Australian Aborigines are highly variable for canine root height. However, the high variability of $I^{\underline{2}}$ root height in the pooled H.sapiens sample stems from the Australian Aborigines; for this dimension, the Australian Aborigines are highly variable and more variable than the Romano-British (F-ratio:$P < 0.001$; H.sapiens (pooled) C.V.=16.8, R-B C.V.=6.9, A.A. C.V.=18.1) $I_{\underline{2}}$ root height is also particularly highly variable in the Australian Aborigines (H.sapiens (pooled) C.V.=12.6, R-B C.V.=10.2, A.A. C.V.=16.7). The Romano-British also have shorter $P_{\underline{3}}$, $M_{\underline{2}}$ and $M^{\underline{2}}$ buccal roots than the Australian Aborigines, but the mean values for these dimensions differ less than for the previously mentioned roots and their ranges

overlap more with the exception of the M^2 buccal roots.

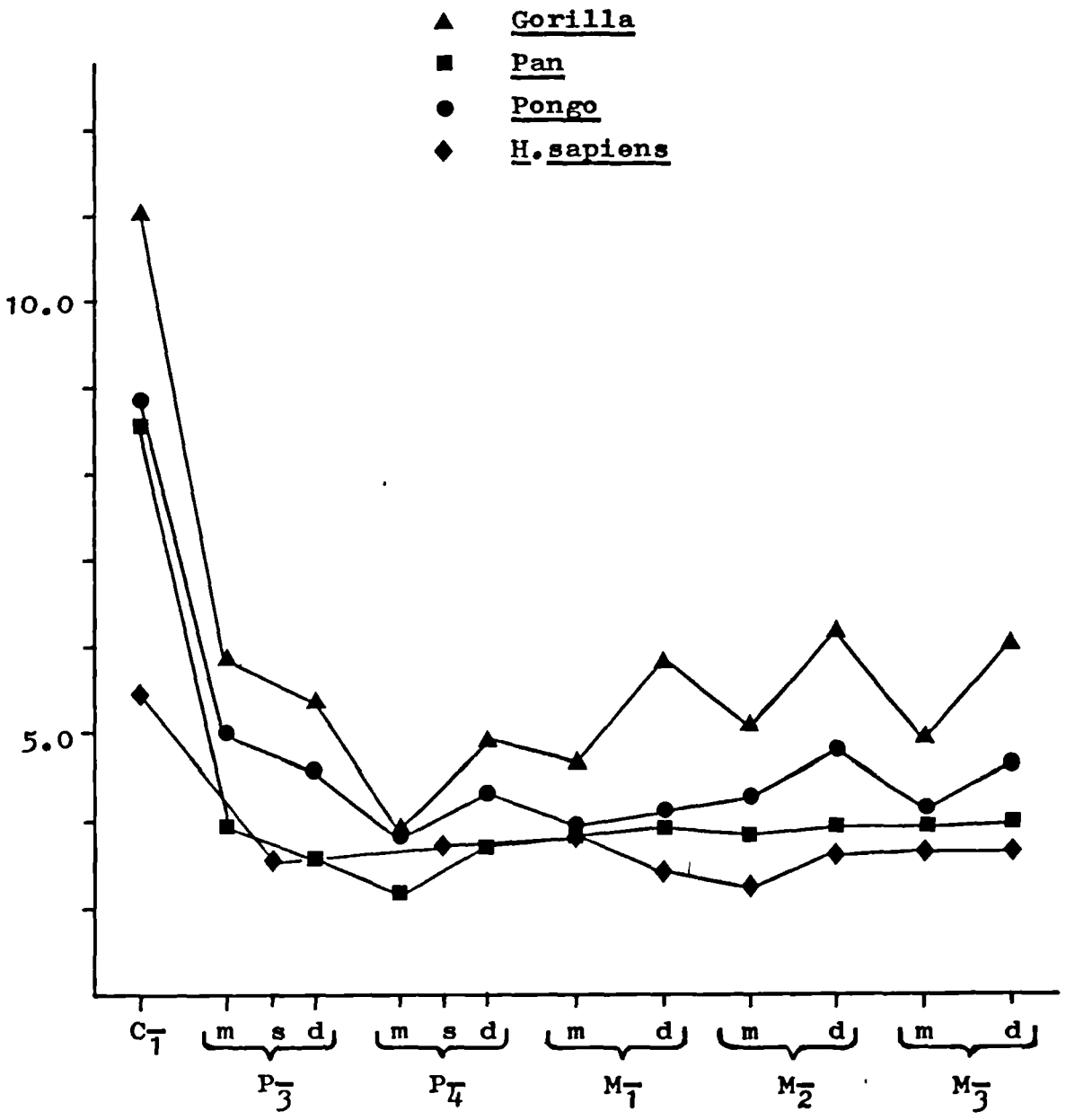
iv) Root mesiodistal diameter

Root mesiodistal diameter was measured for all post-canine roots and for the C_1^- root, but as the radiographic image of the latter was not a true mesiodistal projection, canine root mesiodistal diameter is probably not exactly equivalent to the root mesiodistal diameters of the other teeth. Root mesiodistal diameter was measured perpendicular to the root axis through the point on the axis which represents half the total root height. Additionally, the robusticity of the roots in the pongids and H.sapiens was examined by relating root mesiodistal diámeter to root height in the root robusticity index (root mesiodistal diameter/actual root height x 100). Statistical summaries for root mesiodistal diameter and root robusticity index are given in Appendices D(v) and E(ii), respectively. The statistical significance of differences in mean values and variances between the samples are listed in Appendix F. The mean values of root mesiodistal diameter in the pongids and H.sapiens are plotted in Figs.16 and 17, and those for root robusticity index in Figs.18 and 19.

Summary

Root mesiodistal diameter is generally highly variable in the pongids and H.sapiens, and this contributes to similarity between them for some roots. Nonetheless, marked differences in root mesiodistal diameter are found between the samples. In general, of the pongids Gorilla has the largest root mesiodistal diameters, then Pongo and then Pan.

Fig. 16 : Mean values of mandibular root mesiodistal diameter in the pongids and Homo sapiens .



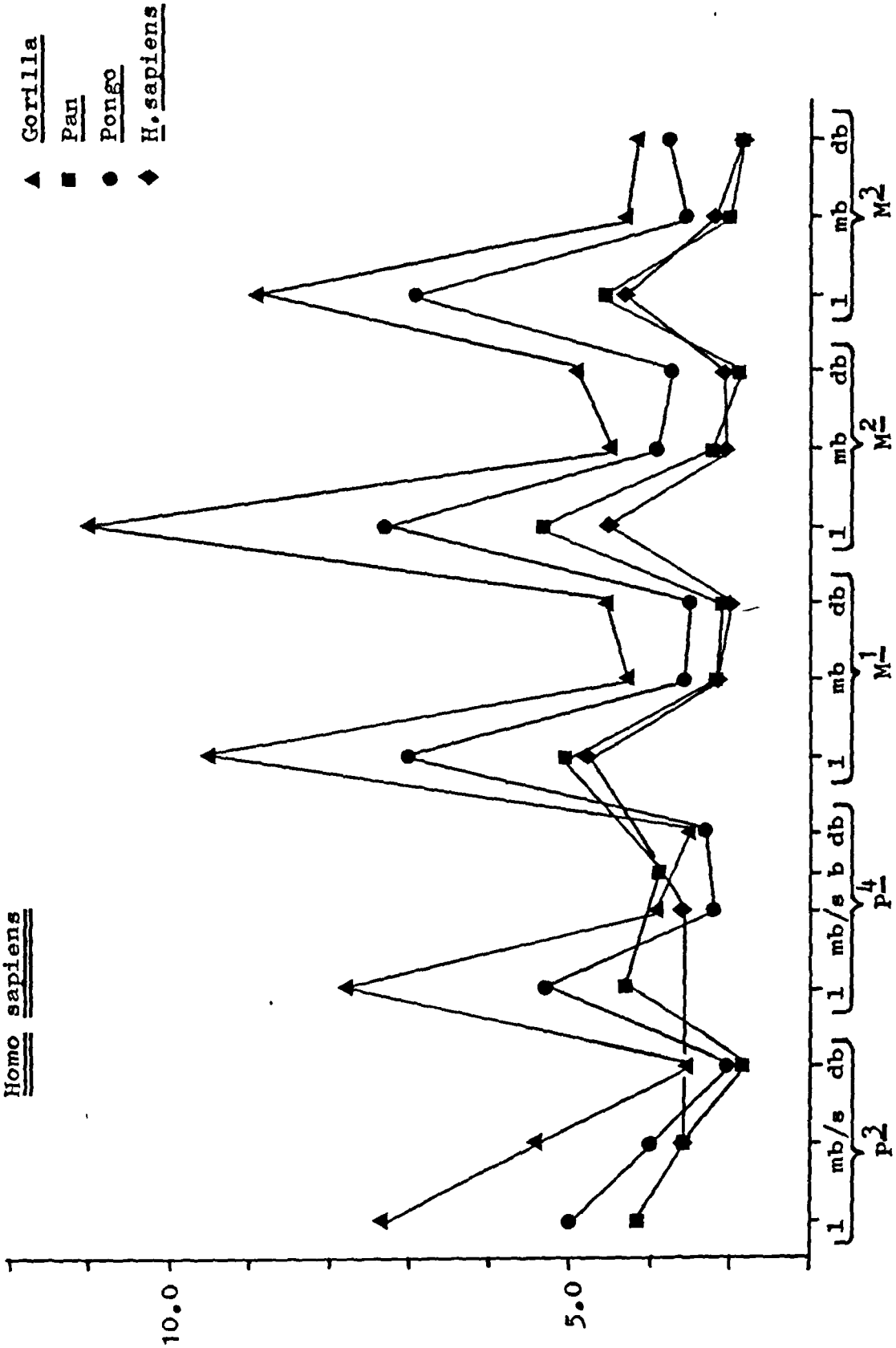


Fig. 17 : Mean values of maxillary root mesiodistal diameter in the pongids and

Fig. 18 : Mean values of the root robusticity index for the mandibular roots of the pongids and Homo sapiens

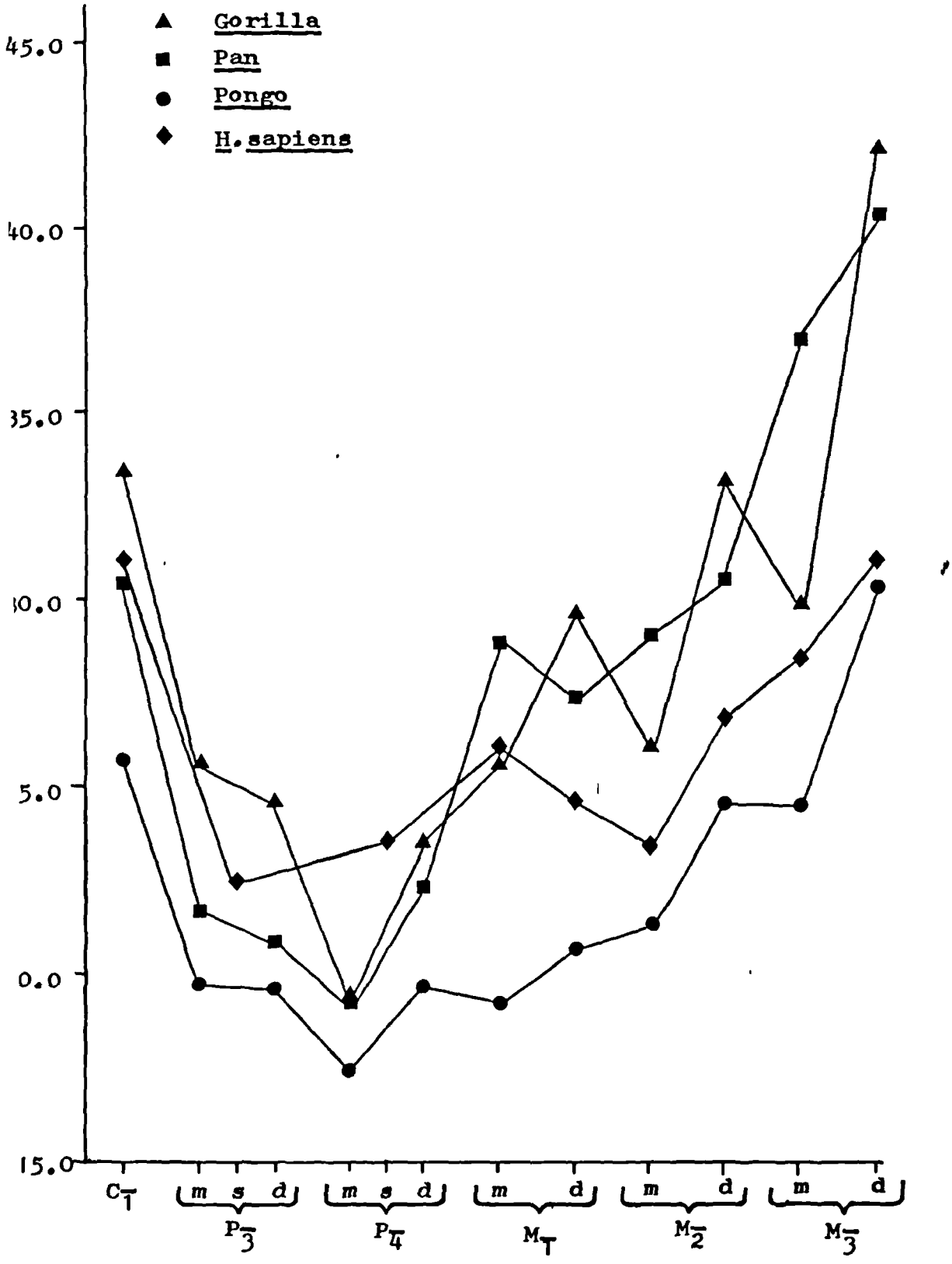
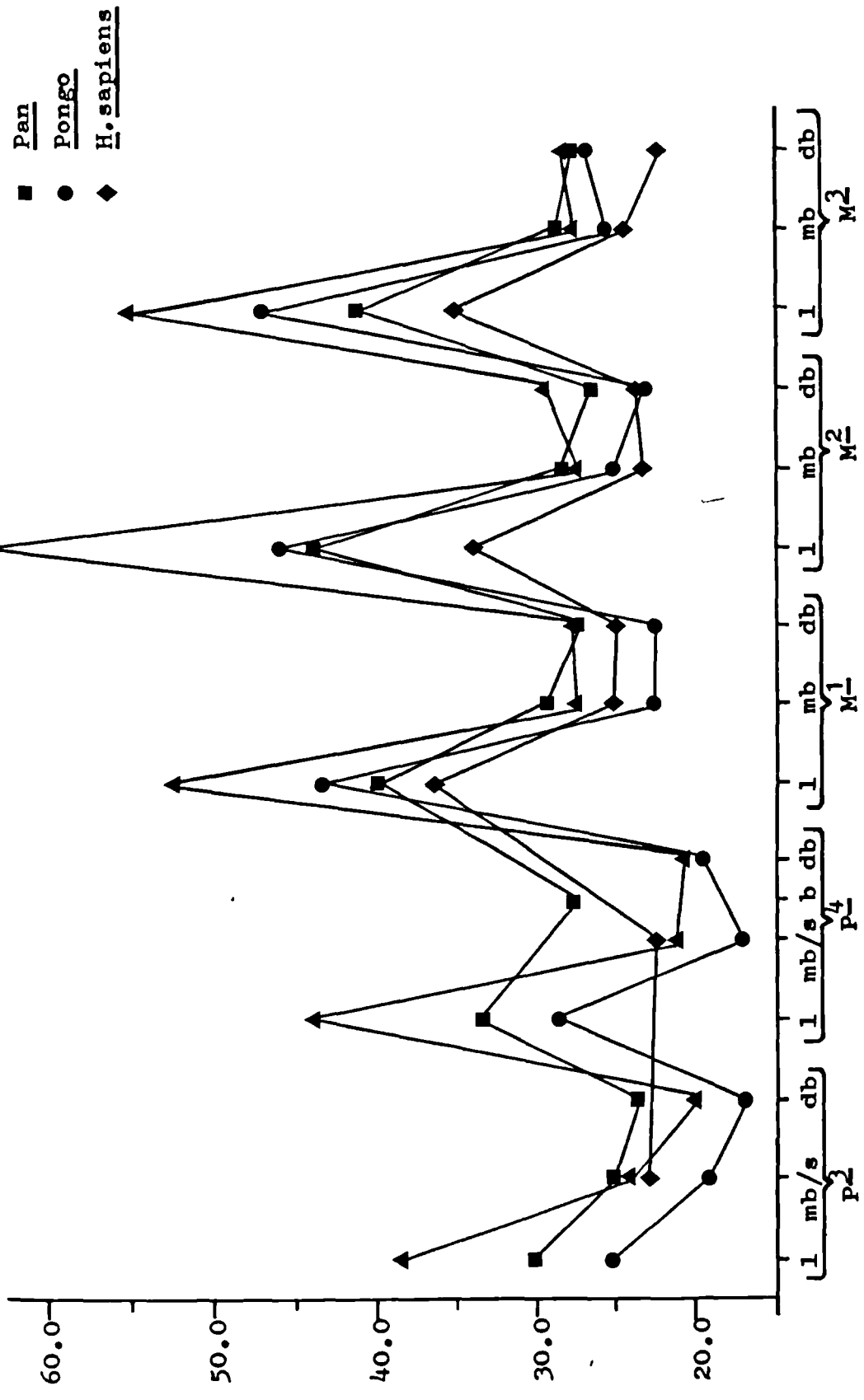


Fig. 19 : Mean values of the root robusticity index for the maxillary roots of the pongids and Homo sapiens



For many of them, the Gorilla and Pongo ranges overlap considerably; they differ most for the mesiodistal diameters of the M_1^- and M_2^- distal roots and the maxillary lingual roots, most of which are much smaller in Pongo. Some root mesiodistal diameters - including that of the C_1^- - are similar in Pongo and Pan, while they differ most for the maxillary molar lingual roots. All root mesiodistal diameters are smaller in Pan than in Gorilla, though their ranges overlap considerably for some mandibular mesial roots. All the maxillary lingual roots and the M_2^- distal and M^2 distobuccal roots are very much smaller in Pan than Gorilla - their ranges being discontinuous for these roots. Thus, of all root mesiodistal diameters, those of the maxillary lingual roots, particularly of the molars, show most difference between the pongids. H.sapiens and Pan are similar for molar root mesiodistal diameters, but the C_1^- and $1RP_3^-$ dimensions are much smaller in H.sapiens. Root mesiodistal diameter in H.sapiens is generally smaller than in Pongo and much smaller than in Gorilla, being most different from them both for the C_1^- and maxillary lingual roots. Thus, H.sapiens differs most from all pongids for the C_1^- root mesiodistal diameter, but also shows comparable difference from Pongo and Gorilla for themaxillary molar lingual root mesiodistal diameters - dimensions which differ most between the pongids. All root mesiodistal diameters are similar in the Romano-British and Australian Aborigines with the exception of the P^3 root which is smaller in the Romano-British.

In the pongids and H.sapiens, high variability is also characteristic of the root robusticity index. However, in

spite of this, marked differences are found between the pongids: the lingual roots of P^3, P^4 and M^2, and the M_1 distal root are more robust in Gorilla than Pongo, and the P^3 buccal roots and particularly the mandibular molar mesial roots are more robust in Pan than Pongo. The robusticity of many roots is similar in Gorilla and Pan, but the maxillary lingual roots are more robust in Gorilla. Canine root robusticity is similar in H.sapiens and the pongids, particularly when compared with Gorilla and Pan. In addition, H.sapiens is most similar to Pan for the M^1 lingual root and the distobuccal roots of M^1 and M^2, and most similar to Gorilla for the mandibular molar mesial roots. Most roots are of similar robusticity in H.sapiens and Pongo. In H.sapiens, the IRP_3 root is much less robust than in Pan, and the M_3 distal root and the maxillary molar lingual roots are much less robust than in Gorilla.

Pongids

With the exceptions of the P_4 mesial root and the distobuccal roots of P^4 and M^3, the root mesiodistal diameters of all roots are smaller in Pongo than in Gorilla - their mean values for these roots being significantly different ($P < 0.001$ all except ($P < 0.01$) C_1). Their mean values are most similar for mandibular premolar roots, maxillary premolar buccal roots - except the P^3 mesiobuccal root, the mandibular molar mesial roots and the maxillary molar mesiobuccal roots; for nearly all these roots their ranges overlap considerably. The general high variability of root mesiodistal diameter contributes to similarity between them (Gorilla $\bar{X}$ C.V.=14.9, Pongo $\bar{X}$ C.V.=14.0) for these roots. Their mean values differ

more for the C_1^- and P^3 mesiobuccal roots, but their ranges for these roots also overlap considerably - both are very highly variable for these dimensions (C.V.: Gorilla C_1^-=26.8, P^3mb=20.2; Pongo C_1^--20.6, P^3mb=19.4). Gorilla and Pongo differ most for the mesiodistal diameters of the distal roots of M_1^- and M_2^- and the maxillary lingual roots, especially those of P^3, P^4 and M^2. The robusticity of a few roots is the same in Gorilla and Pongo; for the P^4 distobuccal root, the M^2 mesiobuccal root and the M^3 buccal roots their mean values are not significantly different and their ranges overlap very considerably. For all other roots ($P < 0.001$ except $P < 0.01$ P_4m, P^3db), the mean values are smaller in Pongo indicating that these roots are more robust in Gorilla. However, the root robusticity index is generally very highly variable in Gorilla ($\bar{X}$ C.V.=17.2), and in Pongo ($\bar{X}$ C.V.=19.0) the value of the coefficient of variation is greater than 15.0 for all roots. This high variability is reflected in the considerable or very considerable overlap between the Gorilla and Pongo ranges for all roots - with a few exceptions. The Gorilla and Pongo mean values differ most for the M_1^- distal root and the lingual roots of P^3, P^4 and M^2, and their ranges overlap much less for these roots than for others. In addition, Gorilla and Pongo differ in their C_1^- ranges; in this instance, the upper part of the Gorilla range is extensive and not overlapped by the Pongo range indicating that some Gorilla specimens have very robust roots.

For a few roots - the C_1^- root, the P^3 buccal roots, the M_1^- roots and the M_3^- mesial root - root mesiodistal diameter is similar in Pongo and Pan. For all other roots, root mesiodist

diameter is smaller in Pan than in Pongo - their mean values being significantly different ($P \leqslant 0.001$ except $P < 0.01$ $\underline{P^4}$mb, $\underline{M^1}$db). However, for many of these roots their ranges overlap considerably, reflecting the general high variability of root mesiodistal diameter in Pan ($\bar{X}$ C.V.=13.8) as in Pongo. Root mesiodistal diameter differs most between them for the maxillary molar lingual roots. However, the robusticity of these roots is similar in Pan and Pongo as both root mesiodistal diameter and root height are greater in Pongo. The smaller Pan mean value for the $\underline{M^3}$ lingual root is significantly different ($P < 0.01$) from that of Pongo, but their ranges overlap considerably, reflecting high variability in both. With the exception of the maxillary lingual roots, the mean values for root robusticity index are greater in Pan than in Pongo, but for most roots their mean values are either not significant or if significant their ranges overlap considerably or very considerably. However, a few roots are clearly more robust in Pan than in Pongo - the buccal roots of $\underline{P^3}$ and particularly the mesial roots of the mandibular molars. The root robusticity index is generally highly variable in Pan ($\bar{X}$ C.V.=15.5) as already noted in Pongo.

The mesiodistal diameters of all roots are smaller in Pan than in Gorilla, their mean values being significantly different ($P < 0.001$). They are most similar in mean values and ranges for the mesial roots of P_4, M_1 and M_3 and the $\underline{P^3}$ distobuccal roots. For all other roots, in spite of the general high variability of this dimension, root mesiodistal diameter is much smaller in Pan, particularly for the M_2 distal

and $M^{\underline{2}}$ distobuccal roots and all maxillary lingual roots as their ranges are discontinuous for these, especially for the lingual roots of $M^{\underline{1}}$ and $M^{\underline{2}}$. However, as root height is also generally shorter in Pan, the robusticity of many roots is similar in Pan and Gorilla. For the $C_{\overline{1}}$ and $P_{\overline{4}}$ roots, the distal roots of $M_{\overline{2}}$ and $M_{\overline{3}}$ and all maxillary buccal roots except the $P^{\underline{3}}$ distobuccal root, their mean values for the root robusticity index are not significantly different. For the mandibular molar mesial roots and the $P^{\underline{3}}$ distobuccal root, the larger Pan mean values are significantly different from those of Gorilla ($P < 0.001$ $M_{\overline{3}}m$; $P < 0.01$ $M_{\overline{1}}m$ $M_{\overline{2}}m$ $P^{\underline{3}}db$) indicating that these roots are more robust in Pan; however, the Pan and Gorilla ranges overlap considerably for these roots, reflecting very high variability in one or both of them. For the $P_{\overline{3}}$ roots, the $M_{\overline{1}}$ distal root and all maxillary lingual roots, the larger Gorilla mean values are significantly different from those of Pan ($P < 0.001$ $P_{\overline{3}}m$ $P_{\overline{3}}d$ $P^{\underline{3}}l$ $M^{\underline{1}}l$ $M^{\underline{2}}l$ $M^{\underline{3}}l$; $P < 0.01$ $M_{\overline{1}}d$ $P^{\underline{4}}l$). Of these roots, Gorilla is clearly more robust for the maxillary lingual roots as their ranges overlap least for these, particularly for the $M^{\underline{2}}$ lingual root.

Homo sapiens

As in the pongids, root mesiodistal diameter is generally highly variable in H.sapiens ($\bar{X}$ C.V.=15.0), particularly for the $C_{\overline{1}}$, $P_{\overline{3}}$, $M_{\overline{1}}$ mesial and $M_{\overline{3}}$ distal roots and the roots of $M^{\underline{2}}$ and $M^{\underline{3}}$, and this contributes to similarity between H.sapiens and the pongids for some roots.

Most molar root mesiodistal diameters are similar in H.sapiens and Pan; the smaller H.sapiens mean values are

significantly different from the Pan mean values only for the M_1 distal root, the M_2 roots and the M^2 lingual root ($P<0.001$ M_1d M_2m M^2l; $P<0.01$ M_2d), but their ranges overlap considerably for these molar roots. The root mesiodistal diameters of the C_1 and $1RP_3$ are much smaller in H.sapiens than in Pan; their mean values are signficantly different ($P<0.001$) and their ranges, particularly for $1RP_3$, overlap much less than for any of the molar roots - however, it should be noted that the Pan sample for $1RP_3$ is small. As C_1 root height is shorter in H.sapiens than in Pan, they are similar for the robusticity of this root. They are also similar for the robusticity of the M^1 lingual root and the distobuccal roots of M^1 and M^2. For all other roots, the smaller H.sapiens mean values for the root robusticity index are significantly different from those of Pan ($P\leqslant 0.001$ except $P\leqslant 0.01$ M_1m M^1mb M^2l M^3mb and M^2db) indicating greater robusticity in Pan; however, with some exceptions, their ranges overlap considerably for these roots, reflecting the generally high variability of the root robusticity index in H.sapiens ($\bar{X}$ C.V.=15.2) as in Pan. H.sapiens has much less robust roots than Pan for $1RP_3$ (N.B. Pan sample small) and, to a lesser extent, for the M_3 roots and the M^3 distobuccal root.

Nearly all root mesiodistal diameters are smaller in H.sapiens than in Pongo; their mean values are significantly different ($P<0.001$) for all roots except the M_1 mesial and the M^3 mesiobuccal roots. However, their ranges overlap considerably for many roots, reflecting the generally high variability of root mesiodistal diameter. Their ranges overlap least for the C_1 and the maxillary lingual roots - even though

these dimensions are mostly very variable in one or both of them - so that these dimensions are much smaller in H.sapiens than in Pongo. As root height is generally shorter in H.sapiens than in Pongo, they are similar for the robusticity of many roots: their mean values for the root robusticity index are either not significantly different, or if significantly different, their ranges overlap considerably reflecting the high variability of root robusticity. Their ranges overlap least for the lingual roots of $M^{\underline{2}}$ and $M^{\underline{3}}$ - which are more robust in Pongo, and for the $M_{\overline{1}}$ mesial root - which is more robust in H.sapiens.

All root mesiodistal diameters are smaller in H.sapiens than in Gorilla - their mean values being significantly different ($P < 0.001$), and most are much smaller in H.sapiens. They differ most for the $C_{\overline{1}}$, the $M_{\overline{3}}$ distal root and the distobuccal roots of $M^{\underline{1}}$ and $M^{\underline{2}}$ - for which their ranges are nearly discontinuous - and especially for the lingual roots of the maxillary molars where their ranges are discontinuous. The robusticity of many roots is similar in H.sapiens and Gorilla, either because their mean values are not significantly different, or because their ranges overlap considerably. However, some roots are much less robust in H.sapiens than in Gorilla; of all roots, their ranges overlap least for the $M_{\overline{3}}$ distal root and for the lingual roots of the maxillary molars - for the $M^{\underline{2}}$ lingual root their ranges are discontinuous.

Romano-British & Australian Aborigines

With the exception of the $P^{\underline{3}}$ root, all root mesiodistal

diameters are similar in the Romano-British and Australian Aborigines - their mean values are not significantly different and their ranges overlap considerably. The P^3 root mesiodistal diameter is smaller in the Romano-British sample than in the Australian Aborigines; the mean values are significantly different ($P < 0.001$) and the ranges overlap less than for any other root. Thus, the particularly high variability of some root mesiodistal diameters in the pooled H.sapiens sample cannot be explained by size difference between the Romano-British and the Australian Aborigines.

v) Height of bifurcation

Height of bifurcation was measured for two-rooted mandibular teeth and three-rooted maxillary teeth, and is the perpendicular distance from the cervical axis to the point of bifurcation - into the mesial and distal roots of mandibular teeth and the mesiobuccal and distobuccal roots of maxillary teeth. The relative height of the bifurcation in the pongids and H.sapiens was examined by relating height of bifurcation to root height in the height of bifurcation index (height of bifurcation/projected root height x 100). Statistical summaries for height of bifurcation and height of bifurcation index are given in Appendices D(vi) and E(iii), respectively, and the statistical significance of differences in mean values and variances are listed in Appendix F. The mean values of height of bifurcation and height of bifurcation index in the pongids and Homo sapiens are plotted in Figs. 20 and 21, respectively.

Fig. 20 : Mean values of height of bifurcation in the pongids and Homo sapiens

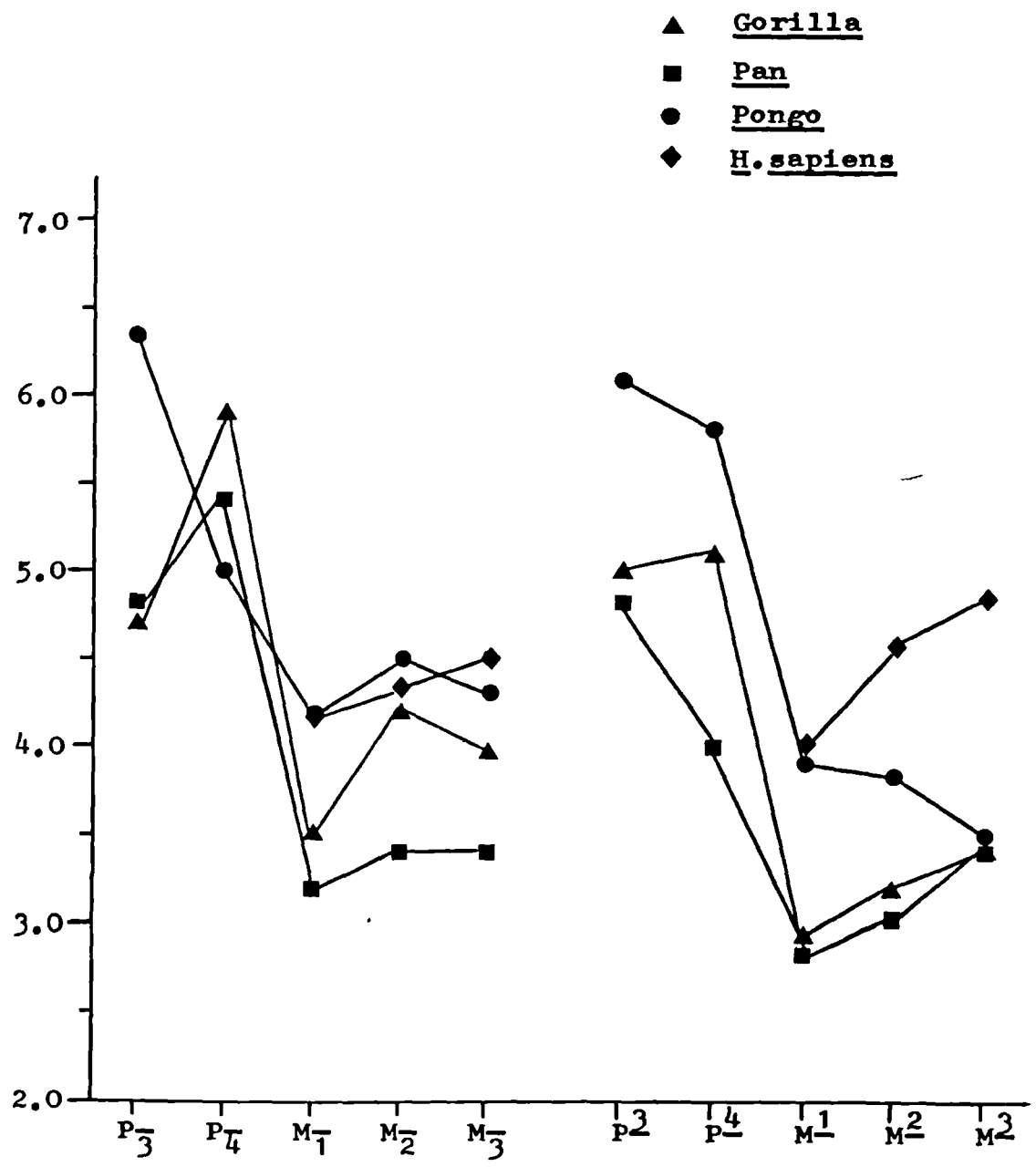
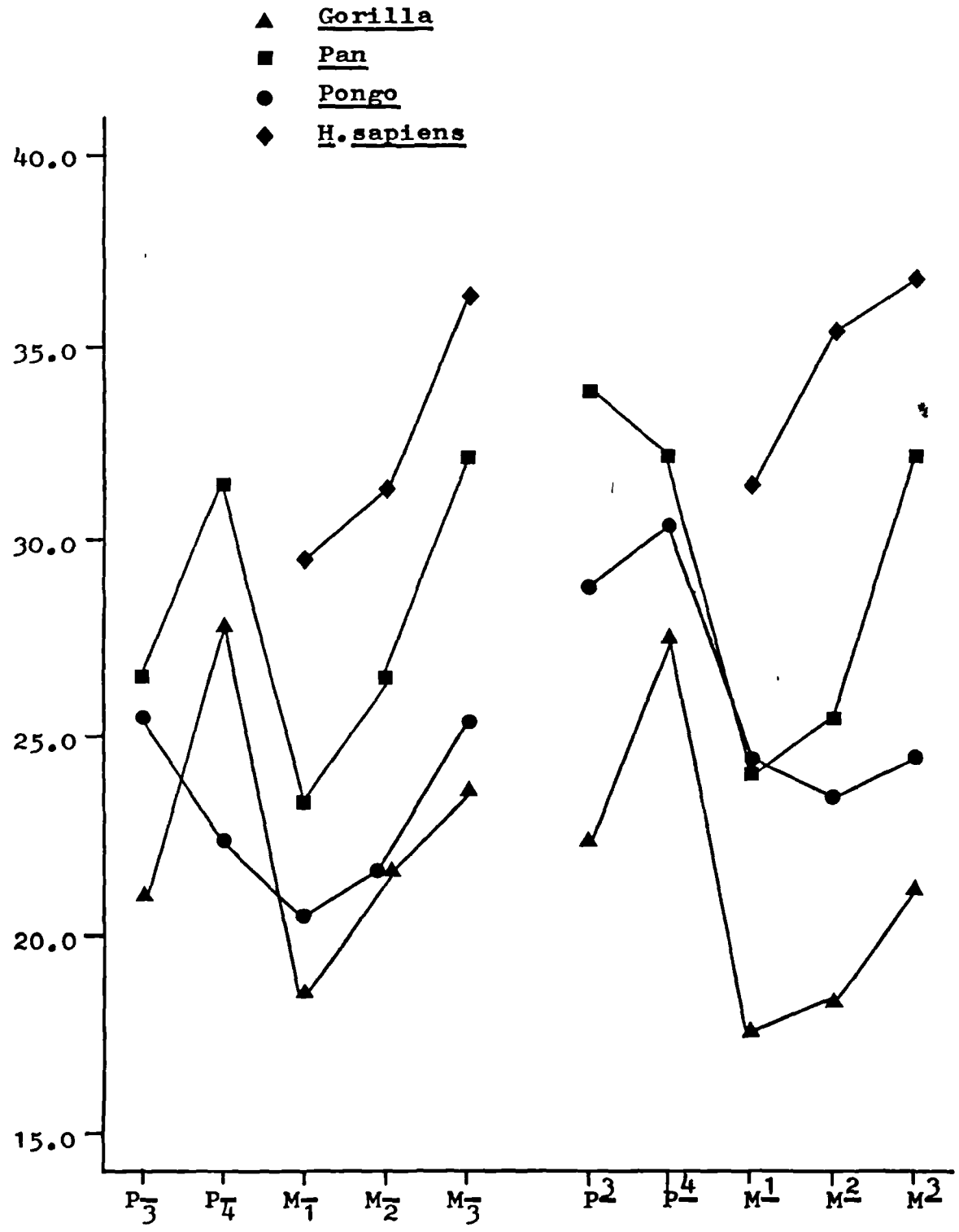


Fig. 21 : Mean values of the height of bifurcation index in the pongids and Homo sapiens



Summary

In the pongids and H.sapiens, height of bifurcation and the height of bifurcation index are very variable; for this reason, ranges may overlap considerably even when mean values differ greatly. Gorilla is particularly highly variable for the maxillary molars. Height of bifurcation is generally similar in the pongids, though for some teeth, it is smaller in Pan - particularly in comparison to Pongo. The H.sapiens molar heights of bifurcation are all larger than those of Pan, but are similar to those of Pongo and, with the exception of $M_{\overline{3}}$, those of Gorilla.

The relative height of bifurcation is greater in Pan than in the other pongids for several teeth; for $P_{\overline{4}}$, $M_{\overline{2}}$ and $M_{\overline{3}}$ in comparison to Pongo and for $M_{\overline{2}}$, $M_{\overline{3}}$, P^3 and M^3 in comparison to Gorilla. Thus, as the P^3 height of bifurcation is also relatively greater in Pongo than Gorilla, both Pan and Pongo differ from Gorilla in this respect. All molar heights of bifurcation are relatively greater in H.sapiens than in Gorilla and Pongo, but differ most in the mandibular molars where there is less overlap in range. In comparison to Pan, only the $M_{\overline{1}}$, M^1 and M^2 heights of bifurcation are relatively greater in H.sapiens.

Pongids

There are no real differences in height of bifurcation between Gorilla and Pongo. Their mean values are significantly different for some teeth ($P \leqslant 0.001$ $P_{\overline{3}}$ $M_{\overline{1}}$ M^1; $P < 0.01$ $P_{\overline{4}}$), but their ranges for these teeth overlap very considerably.

This is because height of bifurcation is very highly variable (Gorilla $\bar{X}$ C.V.=29.8, Pongo $\bar{X}$ C.V.=26.1) - rather more so in the maxillary teeth (Gorilla $\bar{X}$ C.V.=35.9, Pongo $\bar{X}$ C.V.=29.5) than in the mandibular teeth (Gorilla $\bar{X}$ C.V.=23.7, Pongo $\bar{X}$ C.V.=22.6). With the exception of P^3, all relative heights of bifurcation are similar in Gorilla and Pongo. Again, some of their mean values are significantly different ($P < 0.001$ P_4 P^3 M^1 M^2; $P < 0.01$ M_1), but the very great variation of the relative height of bifurcation (Gorilla $\bar{X}$ C.V.=28.5, Pongo $\bar{X}$ C.V.=22.8) results in their ranges overlapping very considerably for these teeth - with the exception of P^3. For P^3, the relative height of the bifurcation is greater in Pongo than Gorilla.

All Pan and Pongo mean values for height of bifurcation are significantly different ($P < 0.001$ M_1 M_2 M_3 M^1; $P < 0.01$ P_3 P^3 M^2) except for P^4, P_4 and M^3. As in the other pongids, height of bifurcation is very variable in Pan ($\bar{X}$ C.V.=27.5) leading to very considerable overlap in the Pan and Pongo ranges for P_3 and M_3. For P^3 and the first and second molars, the Pan and Pongo ranges do not overlap to such a considerable extent so these heights of bifurcation may be considered smaller in Pan. Their mean values for the height of bifurcation index are significantly different for P_4 to M_3 and M^3 ($P \leqslant 0.001$ P_4 M_2 M_3; $P < 0.01$ M_1 M^3), but again, because of high variability in Pan ($\bar{X}$ C.V.=27.5) as in the other pongids, their ranges overlap very considerably for M_1 and M^3. For P_4, M_2 and M_3, the relative height of the bifurcation is greater in Pan than Pongo.

Overall, height of bifurcation is very similar in Gorilla and Pan, only their M_2 mean values are significantly different ($P < 0.001$) and their ranges for this dimension overlap quite considerably. For height of bifurcation index, their mean values are significantly different ($P < 0.001$) for all teeth except P_3, P_4 and P^4, indicating greater relative height of bifurcation in the Pan teeth. The high variability of relative height of bifurcation results in their ranges overlapping considerably for M_1, M^1 and M^2 so that the relative height of bifurcation is only clearly greater in Pan than in Gorilla for M_2 and M_3, P^3 and M^3.

Homo sapiens

As in the pongids, height of bifurcation is highly variable in H.sapiens ($\bar{X}$ C.V.=20.4), and so is the height of bifurcation index ($\bar{X}$ C.V.=19.4). All molar heights of bifurcation are larger in H.sapiens than Pan; their mean values are significantly different ($P < 0.001$) and although their ranges overlap considerably they show sufficient difference to substantiate the indications of larger size in H.sapiens. The H.sapiens and Pan mean values for height of bifurcation index are significantly different ($P \leqslant 0.001$) for the first and second molars, indicating greater relative height in H.sapiens. However, the Pan range completely overlaps the H.sapiens range for M_2.

Overall, height of bifurcation is very similar in Homo sapiens and Pongo; their M^2 and M^3 mean values are significantly different ($P < 0.01$), but their M^2 ranges overlap very considerably, while for M^3 the more extensive Pongo range completely

overlaps the H.sapiens range as this dimension is more variable in Pongo (C.V.=38.1) than H.sapiens (C.V.=23.6). For all the molars, the H.sapiens and Pongo mean values are significantly different ($P < 0.001$) for the height of bifurcation index, indicating greater relative height in H.sapiens, and their mean values differ most for M^2 and M^3. However, the upper part of the Pongo M^3 range almost completely overlaps the H.sapiens range, reflecting greater variability in Pongo (Pongo $\bar{X}$ C.V.=35.8, H.sapiens $\bar{X}$ C.V.=14.7). In fact, their ranges overlap least in the mandibular molars where height of bifurcation index is less variable, particularly in Pongo (Pongo $\bar{X}$ C.V.=16.4, H.sapiens $\bar{X}$ C.V.=17.0), than in the maxillary molars (Pongo $\bar{X}$ C.V.=28.3, H.sapiens $\bar{X}$ C.V.=21.7).

The only molar height of bifurcation which differs clearly between H.sapiens and Gorilla is that of M_3. The H.sapiens and Gorilla mean values for height of bifurcation are significantly different for all molars except M_2 ($P < 0.001$ M_1 M^1 M^2; $P < 0.01$ M_3 M^3), but the Gorilla ranges completely or almost completely overlap those of H.sapiens for all molars except M_3. This reflects the very high variability of height of bifurcation, particularly for the maxillary molar dimensions of Gorilla ($\bar{X}$ C.V.=40.3). For all molars, the larger H.sapiens mean values for the height of bifurcation index are significantl different ($P < 0.001$) from those of Gorilla; the mean values differ most for the maxillary molars, while the ranges differ more for the mandibular molars.

Romano-British & Australian Aborigines

The molar heights of bifurcation are similar in the

Romano-British and Australian Aborigines; none of their mean values are significantly different. The significance of M^3 mean values was not tested owing to very small sample size in the Romano-British.

vi) Root angulation

Root angulation was measured for the incisors and the postcanine teeth, and is the angle between the root axis and a line drawn perpendicular to the cervical axis. All root angulations are in the mesiodistal plane. (A + sign signifies mesial angulation, and a - sign signifies distal angulation). In addition, the divergence between the mesial and distal roots of two-rooted mandibular teeth and between the mesiobuccal and distobuccal roots of three-rooted maxillary teeth was calculated by subtracting the distal/distobuccal root angulation from the mesial/mesiobuccal root angulation. (A + sign signifies divergence, a - sign signifies convergence). Statistical summaries for root angulation and root divergence are given in Appendices D(vii) and E(iv), respectively, and the statistical significance of differences in mean values and variances between the samples are listed in Appendix F. The coefficient of variation was not calculated for these dimensions. The mean values of root angulation in the pongids and H.sapiens are plotted in Figs. 22 and 23, and those for root divergence in Fig. 24.

Summary

In the pongids, differences in root angulation are mainly found in the molar roots. A notable difference in premolar

Fig. 22 : Mean values of mandibular root angulation in the pongids and Homo sapiens

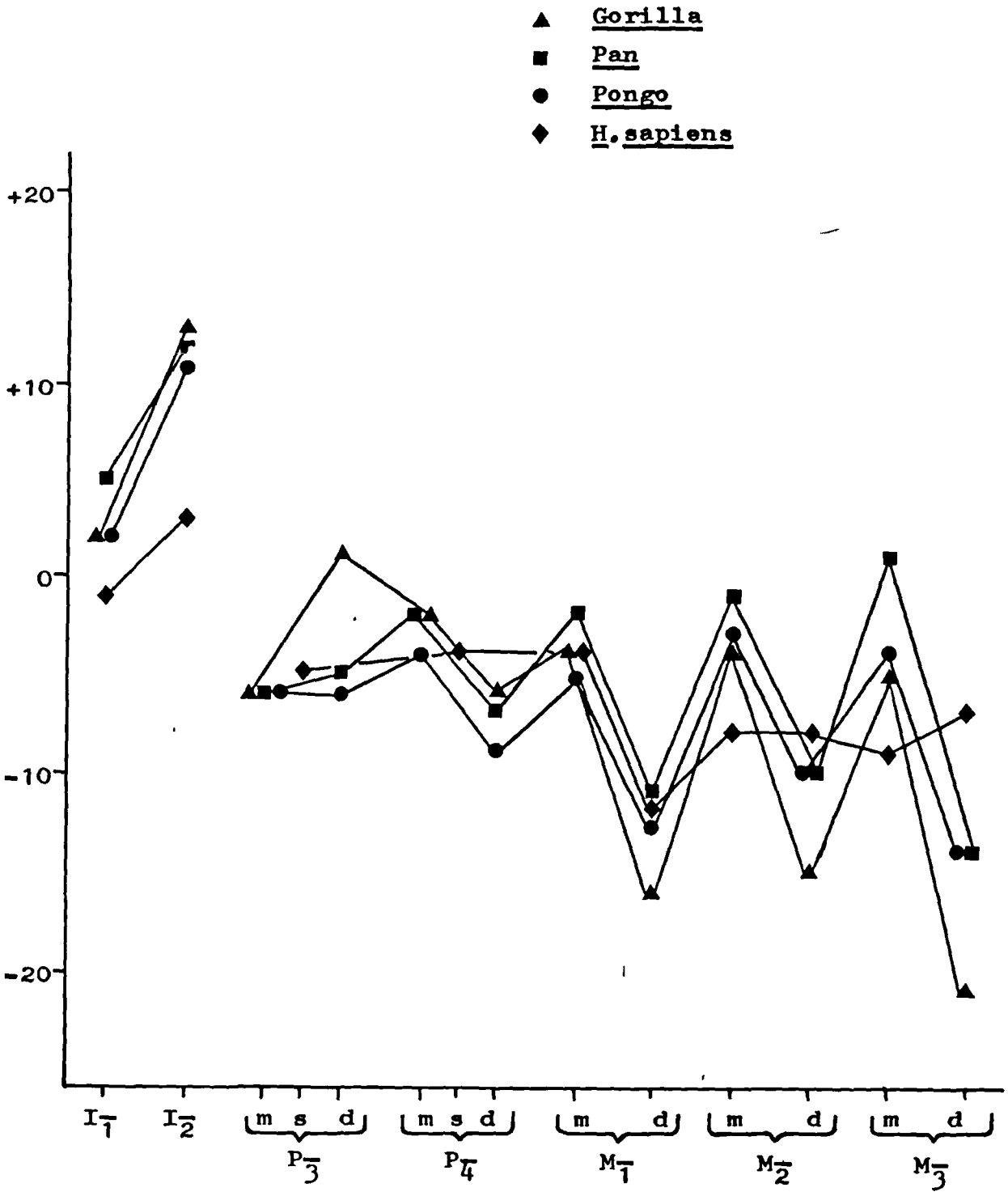


Fig. 23 : Mean values of maxillary root angulation in the pongids and Homo sapiens

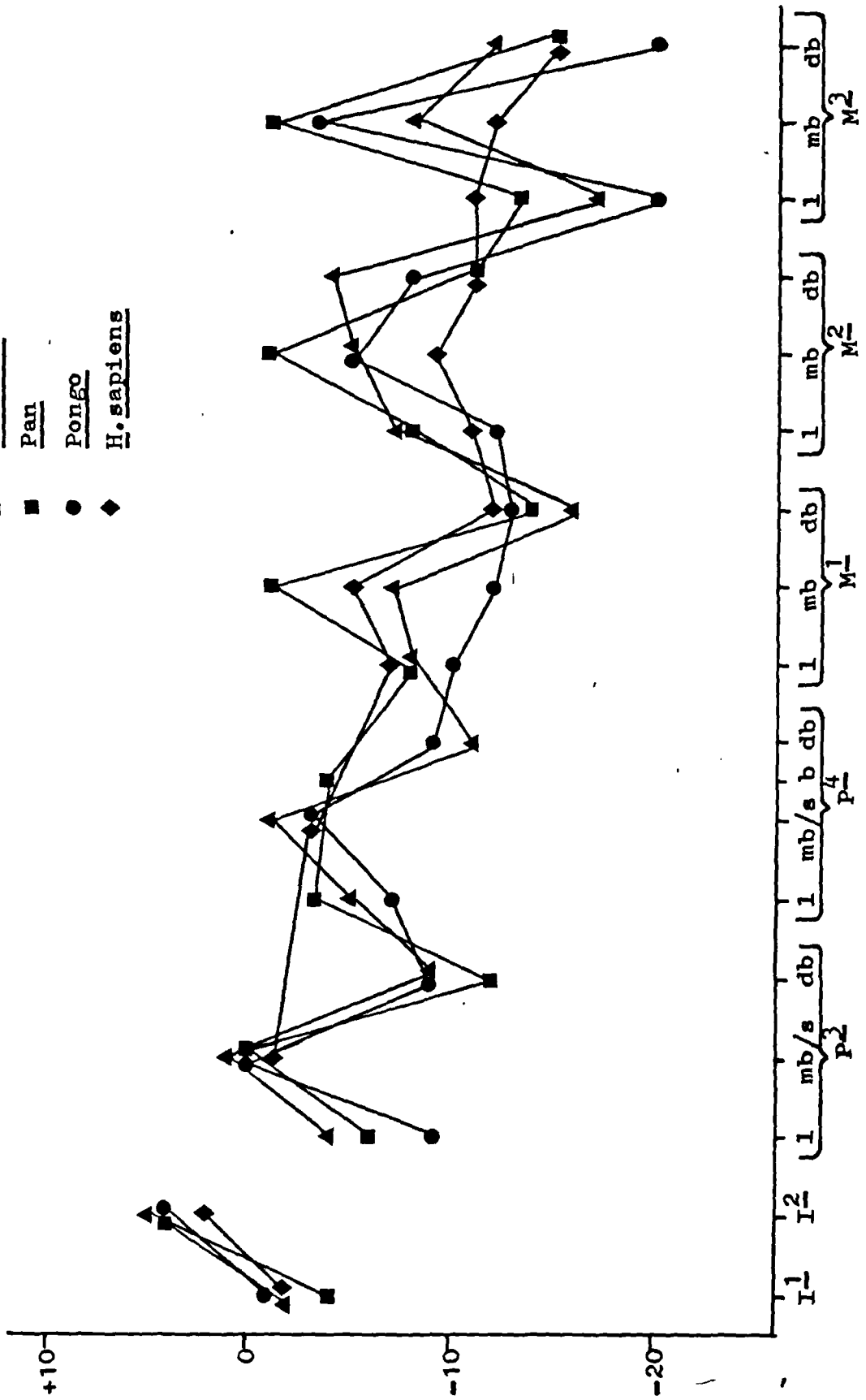
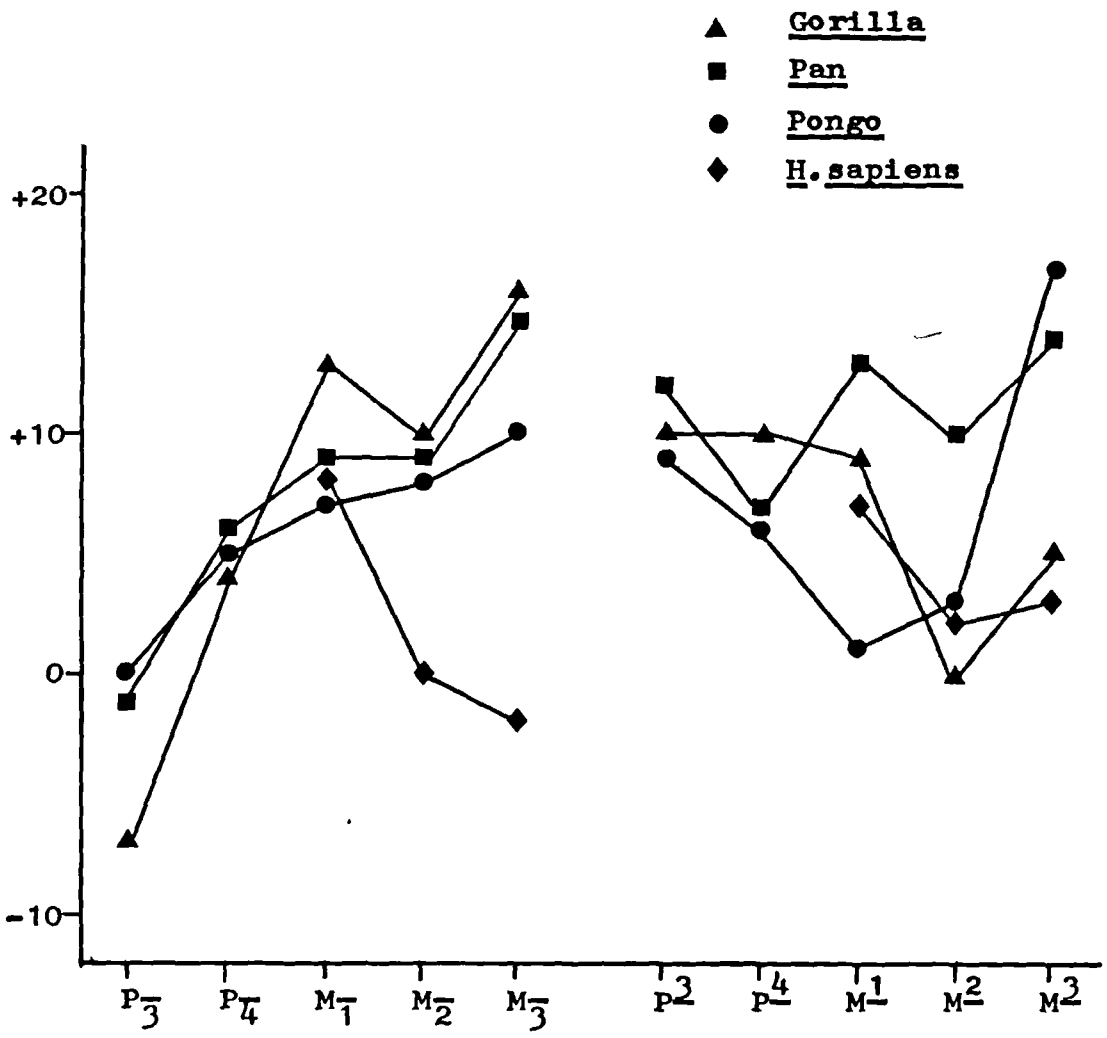


Fig. 24 : Mean values of root divergence in the pongids and Homo sapiens



root angulation is that the Gorilla P_3 distal root tends to be orientated vertically, while this root is angled distally in Pan and Pongo. This results in a difference in root divergence - the P_3 roots converge in Gorilla, but tend to be parallel in the other pongids. The distal angulation of the mandibular molar distal roots is greater in Gorilla than in the other pongids, and it may be very marked in the M_3 distal root. Only in M_1 does this greater distal angulation in Gorilla result in a divergence between the roots which exceeds that in both the other pongids. On the other hand, the divergence between the M^3 buccal roots is less in Gorilla than in both other pongids. In Pongo, only the angulation of the M^2 lingual root differs from both other pongids - the distal angulation of this root being greater in Pongo, but in addition, the M^1 buccal roots are less divergent. The mandibular molar mesial roots and the maxillary molar mesiobuccal roots of Pan tend to be orientated vertically, and thus differ from the distal angulation of these roots in one or both of the other pongids. However, the Pan ranges generally overlap considerably with those of one or both of the other pongids. In M^2, the difference in angulation of the mesiobuccal root contributes to greater divergence between the roots in Pan than in the other pongids. H.sapiens differs from all pongids in the angulation of the mandibular incisor roots, the mesial roots of M_2 and M_3 and the M_3 distal root. The mandibular incisor roots tend to be orientated vertically in H.sapiens, unlike the mesial angulation of the I_1 and particularly I_2 roots in the pongids. The M_2 and M_3 mesial roots show greater distal angulation in H.sapiens, while the distal angulation of the M_3 distal root

is less marked in H.sapiens. This results in differences in root divergence - in H.sapiens, the roots tend to be parallel in M_2 and M_3, unlike the quite marked divergence between the roots in the pongids. Root angulation is generally very similar in the Romano-British and Australian Aborigine samples.

Pongids

Root angulation differs between Gorilla and Pongo for the distal roots of the mandibular cheek-teeth, the lingual roots of P^3 and M^2 and the M^3 distobuccal root ($P \leqslant 0.001$ P_3d M_1d M_2d M_3d P^3l M^3db; $P < 0.01$ P_4d M^2l). In Gorilla the distal angulation of the P_3 and P_4 distal roots is less marked than in Pongo, while that of the mandibular molar distal roots is more marked. Of these roots, they differ most in mean values for P_3 and M_3, and their ranges overlap less for these roots - particularly for the P_3 root - than for the other mandibular distal roots. Notably, the distal angulation of the M_3 distal root may be very marked in Gorilla. For the lingual roots of P^3 and M^2 and for the M^3 distobuccal root, the distal angulation is more marked in Pongo. Of these roots, their mean values differ most for the M^3 root, though their ranges overlap considerably for them all. The more marked distal angulation of the molar distal roots in Gorilla results in greater divergence between the roots in Gorilla than in Pongo ($P \leqslant 0.001$) for M_1 and M_3, but not for M_2. However, their M_3 ranges overlap very considerably. P_3 root divergence also differs between Pongo and Gorilla ($P < 0.001$ the roots tend to be parallel in Pongo and to converge slightly in Gorilla. In the maxillary dentition, the divergence between

the M^{1} buccal roots is greater in Gorilla than in Pongo ($P < 0.001$) - these roots tend to be parallel in Pongo, but for M^{3} the buccal roots diverge more in Pongo than in Gorilla ($P < 0.001$).

For some molar roots, the distal angulation is more marked in Pongo than in Pan ($P \leqslant 0.001$ M_{1}m M^{1}mb M^{3}l; $P < 0.01$ M_{3}m M^{2}l M^{2}mb). They differ most for the M^{1} mesiobuccal root, which tends to be vertically orientated in Pan but angled distally in Pongo. Although the distal angulation of the M_{3} mesial, M^{2} mesiobuccal and M^{3} lingual roots tends to be greater in Pongo, their ranges overlap considerably for these roots - particularly the M_{3} and M^{2} roots. Root divergence differs between Pongo and Pan in M^{1} and M^{2} ($P \leqslant 0.001$). In the M^{1} and M^{2} of Pongo, the buccal roots are both angled distally so that they tend to be more-or-less parallel, but in Pan, the mesiobuccal root tends to be vertically orientated while the distobuccal root is angled distally and this results in quite marked divergence between the buccal roots.

Root angulation differs between Pan and Gorilla for the distal roots of P_{3} and M_{1}, the roots of M_{2} and M_{3}, the maxillary molar mesiobuccal roots and the M^{2} distobuccal root ($P \leqslant 0.001$ all these except ($P < 0.01$) M^{2}mb). For all these roots except the P_{3} distal root and the M^{2} distobuccal root, the distal angulation is more marked in Gorilla; however, their ranges overlap very considerably for the M_{2} distal and M_{3} mesial roots and for the mesiobuccal roots of M^{1} and M^{2}. Root angulation differs most between them in the distal roots of P_{3} and M_{3}. The buccal roots of M^{2} and M^{3} diverge more in

Pan than in Gorilla ($P \leqslant 0.001$). In Corilla, both buccal roots are angled distally and tend to be more-or-less parallel, but in Pan the mesiobuccal roots tend to be vertically orientat while the distobuccal roots are angled distally and so there is quite marked divergence between the buccal roots. Pan and Gorilla also differ in root divergence for P_3^- ($P=0.001$) and M_1^- ($P < 0.01$). The P_3^- roots tend to be parallel in Pan, but converge in Gorilla. As the distal angulation of the M_1^- distal root is greater in Gorilla than in Pan, the divergence between the roots is also greater in Gorilla; however, their ranges overlap very considerably.

Homo sapiens

H.sapiens and Pan differ in root angulation for the mandibular incisor roots, the mesial roots of M_2^- and M_3^- and the M_3^- distal root, and for the maxillary molar mesiobuccal roots ($P < 0.001$ all these except ($P < 0.01$) M^1mb). In H. sapiens, the roots of I_1^- and I_2^- tend to be vertically orientated, unlike the mesial angulation in Pan, but the H.sapiens I_2^- range does almost completely overlap the Pan range. The M_2^- and M_3^- mesial roots are angled distally in H.sapiens, but tend to be vertically orientated in Pan. In contrast, the distal angulation of the M_3^- distal root is less marked in H.sapiens than in Pan, though their ranges do overlap very considerably. In Pan, the maxillary molar mesiobuccal roots tend to be vertically orientated, while in H.sapiens they are angled distally. However, with the exception of the M^3 root, their ranges overlap considerably. Root divergence is greater in Pan than in H.sapiens for all molars except M_1^- ($P \leqslant 0.001$

M_2 M_3 M^1 M^2; $P < 0.01$ M^3) because all molar roots are angled distally in H.sapiens, but in Pan the mandibular molar mesial roots and the maxillary molar mesiobuccal roots tend to be vertically orientated while the distal and distobuccal roots are angled distally.

The roots which differ in angulation between H.sapiens and Pan also differ between H.sapiens and Pongo with the exception of the M^2 mesiobuccal root and the addition of the M^3 lingual root ($P < 0.001$ I_1 I_2 M_2m M_3d M^1mb M^3l; $P < 0.01$ M_3m M^3mb). For the mandibular incisor and molar roots, the pattern is the same: the incisor roots tend to be vertically orientated in H.sapiens, but angled mesially in Pongo; the distal angulation of the M_2 and M_3 mesial roots is more marked in H.sapiens, but that of the M_3 distal root is less marked. The difference between them for the M^3 mesiobuccal root is similar to that between H.sapiens and Pan, but the distal angulation of the M^1 mesiobuccal and M^3 lingual roots is greater in Pongo than in H.sapiens. Root divergence is greater in Pongo than in H.sapiens for M_2, M_3 and M^3 ($P < 0.001$); in H.sapiens the roots of M_2 and M_3 and the buccal roots of M^3 tend to be more-or-less parallel. On the other hand, the M^1 buccal roots diverge more in H.sapiens than in Pongo ($P < 0.0$] the distal angulation of both these roots is marked in Pongo so that they tend to be parallel.

H. sapiens and Gorilla also differ in angulation for the mandibular incisor roots, the M_2 and M_3 mesial roots and the M_3 distal root, and also for the distal roots of M_1 and M_2,

the M^{2}_{-} mesiobuccal root and the distobuccal root of M^{1}_{-} and M^{2}_{-} ($P \leqslant 0.001$ $I_{\bar{2}}$ $M_{\bar{1}}d$ $M_{\bar{2}}m$ $M_{\bar{2}}d$ $M_{\bar{3}}d$ $M^{1}_{-}db$ $M^{2}_{-}db$; $P < 0.01$ $I_{\bar{1}}$ $M_{\bar{3}}m$ $M^{2}_{-}mb$). The incisor roots, particularly that of $I_{\bar{2}}$, are angled mesially in Gorilla, but tend to be vertical in Homo sapiens. The distal angulation of the mandibular molar distal roots, particularly the $M_{\bar{3}}$ distal root, is greater in Gorilla than in H.sapiens, while that of the $M_{\bar{2}}$ and $M_{\bar{3}}$ mesial roots is less marked in Gorilla. This leads to difference in root divergence between them: the divergence between the roots of the mandibular molars is greater in Gorilla than in H.sapiens and the difference between them increases from $M_{\bar{1}}$ to $M_{\bar{3}}$. Of the maxillary roots, the distal angulation is greater in H.sapiens for the M^{2}_{-} buccal roots, but greater in Gorilla for the M^{1}_{-} mesiobuccal root. However, their ranges overlap very considerably for the M^{1}_{-} distobuccal and M^{2}_{-} mesiobuccal roots.

Romano-British & Australian Aborigines

Root angulation is similar in the Romano-British and Australian Aborigines for nearly all roots; they differ ($P < 0.01$ only for the $M_{\bar{1}}$ mesial root and the P^{4}_{-} root. The distal angulation of these roots is greater in the Australian Aborigine

vii) Summary

The variability of the dimensions in the comparative samples

The variability of dimensions has an important role in taxonomic assessment. As noted by Simpson et al (1960), taxonomic comparison is more reliably based on characters which vary little than on those which are highly variable.

In the pongids and Homo sapiens, the root dimensions are more variable than the crown dimensions (Table 14), and this is in agreement with the observation made on the Teso of Uganda that root height was more variable than the dimensions of the crown (Barnes, 1969). In each sample, the variability of the two crown dimensions is similar and the average of the coefficients of variation for each crown dimension is low, being less than 10.0 in each sample except the pooled H.sapiens sample. The variability documented in this study for the crown dimensions is similar to that previously reported for the pongid dentition (Mahler, 1973; Pilbeam, 1969; Schuman & Brace, 1954) but tends to be greater than that previously recorded for the modern human dention (Barnes, 1969; Moss et al, 1967, Nelson, 1938; Selmer-Olsen, 1949). This stems from the fact that the Homo sapiens sample is heterogeneous and that there is a size difference between the subsamples for most tooth crowns. In each subsample, the coefficients of variation are smaller than in the pooled sample for all crown dimensions except the mesiodistal diameters of some incisors. With the exception of height of bifurcation, the average value of the coefficients of variation falls generally between 10.0 and 15.0 in each comparative sample. Neck mesiodistal diameter is generally the least variable - being only slightly more variable than the crown dimensions. Location of bifurcation is the next most variable, followed by root height and root mesiodistal diameter. The variability of root height documented in this study for the Romano-British and Australian Aborigines is much the same as that recorded in studies on other modern human groups (Barnes, 1969; Moss et al, 1967, Nelson, 1938; Selmer-Olsen,

Table 14: The variability of the root and crown dimensions in the comparative samples

	Gorilla			Pan			Pongo			H.sapiens			Romano-British			Aust. Aborigines		
	$\bar{X}$	C.V.	N	$\bar{X}$	C.V.	N	$\bar{X}$	C.V.	N	$\bar{X}$	C.V.	N	$\bar{X}$	C.V.	N	$\bar{X}$	C.V.	N
Dimensions																		
neck mesiodistal diameter	11.2		10	9.1		10	10.1		10	11.9		10	8.4		10	8.8		10
location of bifurcation	12.6		10	12.2		9	13.7		10	14.1		6	10.7		5	12.0		6
actual root height	14.3		30	13.6		29	15.1		30	13.8		24	10.7		21	13.4		24
root mesiodistal diameter	14.9		26	14.0		25	14.0		26	15.0		20	14.0		17	14.1		20
height of bifurcation	29.8		10	28.6		9	26.1		10	20.4		6	20.3		5	18.6		6
crown mesiodistal diameter	9.1		15	8.0		15	8.5		15	10.5		15	7.8		15	8.4		15
crown buccolingual diameter	9.7		15	7.3		15	8.4		15	10.1		15	7.6		15	6.2		15
Indices																		
location of bifurcation index	7.1		5	7.7		5	7.0		5	7.7		3	-		-	-		-
root robusticity	17.2		26	16.1		25	19.0		26	15.2		20	-		-	-		-
height of bifurcation	28.5		10	27.1		9	22.8		10	19.4		6	-		-	-		-

N = number of coefficients of variation used to calculate mean value

1949). In all samples, height of bifurcation is very highly variable - the average of the coefficients of variation falls between 20.0 and 30.0 for most samples. In the Teso of Uganda, Barnes (1969) commented upon wide variation in the proportion of the root beyond the bifurcation. The variability of the root indices follows very much from the variability of the constituent dimensions; the variability of height of bifurcation index is very similar to that of the dimension height of bifurcation, and root robusticity index is generally slightly more variable than either of the constituent dimensions. However, location of bifurcation index is less variable than either of the constituent dimensions - neck mesiodistal diameter and location of bifurcation - and is also less variable than the crown dimensions.

In addition to variability differing between dimensions, a pattern of differing variability within the dentition may be identified for some dimensions. In the primate dentition, crown dimensions are most variable in the canine region, of intermediate variability in the incisors and are least variable in the cheek-teeth (Gingerich & Schoeninger, 1979). As M1, or sometimes M2, is usually the least variable of the cheek-teeth, these are suggested to be the best teeth on which to base the diagnosis of closely related species (Gingerich, 1974; Gingerich & Schoeninger, 1979). In this study, the pattern identified by Gingerich and Schoeninger (1979) is clearly demonstrable in the pongid mandibular dentition for most dimensions. For the dimensions crown mesiodistal diameter and crown buccolingual diameter, neck mesiodistal diameter, location of bifurcation and height of bifurcation,

where applicable the $C_{\overline{1}}$ is relatively highly variable, the incisors and $P_{\overline{3}}$ show intermediate variability and the cheek teeth are relatively least variable with $M_{\overline{1}}$ or $M_{\overline{2}}$ usually being least variable of all. For mandibular root height and root mesiodistal diameter, the pattern is not so evident; the $C_{\overline{1}}$ is relatively highly variable - with the exception of the former dimension in Gorilla, but for root height the cheek teeth may be more variable than the incisors and for both dimensions neither $M_{\overline{1}}$ nor $M_{\overline{2}}$ may be the least variable tooth. For example, for these dimensions $P_{\overline{4}}$ is the least variable mandibular tooth in Gorilla. Nor is the pattern of differing variability within the dentition as clear in the pongid maxillary dentition ($C^{\overline{1}}$ not measured), particularly for the root dimensions. For most dimensions, the pattern is not clearly present in the dentition of H.sapiens. In the mandibular dentition, either because the $C_{\overline{1}}$ is not relatively highly variable or because the cheek-teeth are as variable as the incisors. However, for most dimensions $M_{\overline{1}}$ is the least variable tooth. Thus, the pattern of variability identified for the crowns by Gingerich and Schoeninger (1979) is not found in all dimensions of all the samples, though it is more identifiable in the mandibular dentition than in the maxillary. As the root dimensions are generally more variable in the maxillary dentition, particularly in the buccal roots of the pongid cheek teeth, this suggests that, generally, the root dimensions of the mandibular dentition will prove more useful in taxonomic comparison than those of the maxillary dentition.

Homo sapiens compared with the pongids

As Homo sapiens and the pongids differ for premolar root number, direct comparison cannot be made for most premolar root dimensions although single-rooted $P_{\overline{3}}$ ($1RP_{\overline{3}}$) dimensions can be compared in H.sapiens and Pan.

Similarity in size between Homo sapiens and the pongids is found only in molar dimensions, and most extensively in comparison to Pan. Overall, the size of molar roots and crowns does not distinguish clearly between H.sapiens and Pan. Many molar dimensions are not significantly different between them, and for those that are, their ranges usually overlap very considerably. Only a few molar dimensions are of similar size in H. sapiens and Pongo, and these are root dimensions including the $M^{\overline{3}}$ buccal root heights and the mandibular molar heights of bifurcation. Otherwise, the molar crown dimensions and most molar root dimensions are significantly smaller in H.sapiens than in Pongo. However, for many of these dimensions their ranges overlap considerably. Only for the $M^{\overline{3}}$ buccal root heights and the $M_{\overline{2}}$ height of bifurcation are H.sapiens and Gorilla of similar size, otherwise the molars of H.sapiens are generally much smaller than those of Gorilla.

The molars of H.sapiens and the pongids are similar in another respect. There are no real differences between them in the relative mesiodistal positioning of the bifurcation in the mandibular molars. Also, root robusticity is similar in H.sapiens and each of the pongids for some molar roots.

Homo sapiens differs most markedly from all the pongids in dimensions of the mandibular canine and premolars, and of the central incisors. The mean values of all $C_{\bar{1}}$ root and crown dimensions are very much smaller in H.sapiens than in the pongids, but there tends to be more overlap in range between them for the root dimensions than for the crown dimensions. Of the $C_{\bar{1}}$ dimensions, the H.sapiens and Gorilla ranges overlap for root height and root mesiodistal diameter, but not for neck mesiodistal diameter, crown mesiodistal diameter or crown buccolingual diameter. The H.sapiens ranges overlap those of Pan and Pongo for all $C_{\bar{1}}$ dimensions except crown mesiodistal diameter, particularly for root mesiodistal diameter in comparison to both, and for root height in comparison to Pan. The $C_{\bar{1}}$ crown dimensions appear less variable in H.sapiens than in the pongids, while the root dimensions appear of comparable variability. Although the $C_{\bar{1}}$ is much smaller in H.sapiens than in the pongids, it is notable that $C_{\bar{1}}$ root robusticity is similar in H.sapiens, Pan and Gorilla. As H.sapiens and the pongids differ in mandibular premolar root number, they can be directly compared only for the crown dimensions and neck mesiodistal diameters of the mandibular premolars, and of these dimensions, both neck mesiodistal diameters and the $P_{\bar{3}}$ crown mesiodistal diameter are very much smaller in H.sapiens than in the pongids. For these three dimensions, the H.sapiens ranges are discontinuous from those of Gorilla and Pongo - and to a greater degree than for any of the $C_{\bar{1}}$ dimensions - but overlap those of Pan. In the pongids, these premolar dimensions

appear appreciably less variable than their $C_{\bar{1}}$ counterparts, but not in H.sapiens. Mandibular premolar root height and root mesiodistal diameter can be directly compared between H.sapiens and Pan (N=9) for $1RP_{\bar{3}}$. While $1RP_{\bar{3}}$ root height does not differ significantly between them, the marked difference between the H.sapiens and Pan mean values for $1RP_{\bar{3}}$ root mesiodistal diameter is significant ($P < 0.001$) and their ranges do not overlap. With the exception of $I_{\bar{1}}$ root height, all central incisor dimensions are much smaller in H.sapiens than in any of the pongids. The H.sapiens range does not overlap that of any pongid for the $I^{\underline{1}}$ neck mesiodistal diameter, nor does it overlap that of Pongo for the $I_{\bar{1}}$ neck mesiodistal diameter or the crown dimensions of $I^{\underline{1}}$ and $I_{\bar{1}}$, nor that of Gorilla for the crown dimensions and root height of $I^{\underline{1}}$. In addition to the central incisor dimensions, the crown buccolingual diameters of the lateral incisors are much smaller in Homo sapiens than in the pongids. There is no overlap between the H.sapiens and pongid ranges for the $I_{\bar{2}}$ dimension, and none between the H.sapiens and Gorilla ranges for the $I^{\underline{2}}$ dimension.

In addition to the outlined ways in which H.sapiens differs from the pongids collectively, H.sapiens differs markedly in other ways from each of the individual pongids, particularly Pongo and Gorilla. For several incisor dimensions ($I_{\bar{2}}$ neck MD, $I_{\bar{1}}$ root ht, $I^{\underline{2}}$ root ht, $I^{\underline{2}}$ crown MD), H.sapiens and Pan differ markedly in mean value. However, their ranges for these dimensions overlap considerably, reflecting high variability of the dimensions, particularly in H.sapiens. Only for $I_{\bar{2}}$ crown mesiodistal

diameter do H.sapiens and Pan differ appreciably in both mean value and range. In addition, the H.sapiens and Pan mean values of root robusticity for several roots ($_{1}^{1}RP_{3}$, $M_{3}m$, $M_{3}d$, M^{2}_{1}, $M^{3}db$) are markedly different, but, reflecting the general high level of variability of this index, their ranges overlap considerably. In comparison to Pongo, the premolar crowns are much smaller in H.sapiens. There is no overlap in range between them for both crown dimensions of P_{4} or the crown mesiodistal diameters of P^{3} and P^{4}, while their ranges overlap slightly for the crown buccolingual diameters of P_{3} and the maxillary premolars. Otherwise, the M_{2} roots and particularly the mandibular incisor roots are shorter in H.sapiens than Pongo, though, with the exception of I_{1} root height, there is overlap in their ranges for these root heights. Their ranges also overlap for the maxillary molar lingual root mesiodistal diameters, but these are clearly smaller in H.sapiens than in Pongo, particularly the M^{2} dimension. Comparison of the root and crown dimensions of Gorilla and H.sapiens shows that there are few dimensions which are not much smaller in the latter than in the former. For most dimensions, the ranges of Gorilla and H.sapiens are either discontinuous or overlap only slightly. However, for certain dimensions - notably, dimensions of the lateral incisors (I_{2} crown MD, I_{2} neck MD, I^{2} crown MD, I^{2} neck MD, I^{2} root height) and many molar root heights ($M_{1}m$, $M_{3}m$, $M_{3}d$, $M^{1}mb$, $M^{1}db$, M^{2}_{1}, $M^{2}mb$, $M^{2}db$, $M^{3}mb$, $M^{3}db$) amongst others (M_{1} crown BL, $M_{1}m$ root MD, M_{2} ht.bifurc, $M^{2}mb$ root MD, M^{3} loc.bifurc, $M^{3}db$ root MD) - their ranges overlap more, reducing the difference between them.

The pongids

More difference is found between the pongids in the root and crown dimensions of the postcanine dentition than for dimensions of the anterior teeth. Generally, the size of the incisors and the $C_{\bar{1}}$ does not clearly distinguish between the pongids. Some dimensions are significantly different between them, but for the most part the mean differences are small and/or their ranges overlap considerably. Gorilla and Pongo are particularly similar for the root heights of the anterior dentition; Gorilla and Pan are particularly similar for most incisor crown mesiodistal diameters; while Pan and Pongo are similar for mesiodistal diameters of the $C_{\bar{1}}$ and lateral incisors. However, some clear differences are evident between the pongids: $I_{\bar{1}}$ root height is clearly smaller in Pan than in the other pongids, while $I_{\bar{1}}$ crown mesiodistal diameter is larger in Pongo than in the others. All the $C_{\bar{1}}$ dimensions - both root and crown - are usually highly variable in the pongids, and this contributes to the apparent similarity between them for this tooth. All the pongids differ markedly for certain molar dimensions - the $M^{\underline{1}}$ crown buccolingual diameter, the $M^{\underline{1}}$ and $M^{\underline{2}}$ lingual root mesiodistal diameters, the mandibular molar neck mesiodistal diameters and the $M_{\bar{2}}$ location of bifurcation - which are largest in Gorilla, of intermediate size in Pongo and smallest in Pan. In addition to these dimensions, each pongid differs in other postcanine dimensions when compared with each other pongid.

For many postcanine dimensions, the Gorilla and Pongo mean values are significantly different - usually

indicating larger size in Gorilla - but their ranges overlap considerably. Gorilla and Pongo appear to differ most for maxillary lingual root mesiodistal diameters, not only for the M^1 and M^2 as previously mentioned, but also for the maxillary premolars. The distal root mesiodistal diameters of M_1 and M_2 are also clearly smaller in Pongo than in Gorilla, though there is more overlap in range than is usually the case for the maxillary lingual roots. The differences in root mesiodistal diameter between Gorilla and Pongo contribute to greater robusticity of the maxillary premolar lingual roots and the M_1 distal root in Gorilla. All molar crown mesiodistal diameters, particularly those of M^2 and M^3, are clearly smaller in Pongo than in Gorilla, and in each jaw, their ranges overlap less for the second and third molars than for the first molar. While Gorilla and Pongo do not differ so clearly for corwn buccolingual diameter, this dimension is smaller in Pongo for the maxillary premolars and M^1, and also for M_3. As noted previously, the mandibular molar neck mesiodistal diameters show clear difference between the pongids.

Comparison of the dimensions in Pan and Pongo indicates that they differ quite markedly for the height of many roots, including, amongst others, the mandibular molar roots, the P_3 mesial root and the roots of P^3. Of these roots, their ranges overlap least for the mesial roots of the mandibular molars and the P^3 lingual root. As noted previously in connection with all pongids, there is clear difference between Pan and Pongo for the

maxillary molar lingual root mesiodistal diameters and the mandibular molar neck mesiodistal diameters, but additionally the $P_{\overline{3}}$ and, particularly, the $P_{\overline{4}}$ neck mesiodistal diameters are clearly smaller in Pan than in Pongo. In addition, Pan and Pongo differ for many crown dimensions. The crown mesiodistal diameters of the maxillary premolars and $M^{\underline{3}}$, and of $P_{\overline{4}}$ to $M_{\overline{3}}$, and the crown buccolingual diameters of the maxillary cheek-teeth and $P_{\overline{3}}$ to $M_{\overline{1}}$ are smaller in Pan than in Pongo. Of the crown dimensions, there is least overlap in range for the $P^{\underline{4}}$ crown buccolingual diameter and both dimensions of $P_{\overline{4}}$ and $M_{\overline{1}}$.

Nearly all the dimensions of the Pan postcanine dentition are clearly much smaller than those of Gorilla, and difference between them is sufficiently marked for their ranges to be discontinuous for many dimensions. Of the root dimensions, they appear most different for the root mesiodistal diameters of the maxillary lingual roots and of the $M^{\underline{2}}$ distobuccal and $M_{\overline{2}}$ distal roots, and, to a lesser degree, for the neck mesiodistal diameters of $P_{\overline{4}}$ to $M_{\overline{3}}$ and the $M_{\overline{2}}$ and $M_{\overline{3}}$ location of bifurcation. There is no overlap between the Pan and Pongo ranges for any of these root dimensions, nor is there for the crown mesiodistal and buccolingual diameters of $P^{\underline{3}}$ to $M^{\underline{2}}$ and of $P_{\overline{4}}$ to $M_{\overline{3}}$.

Part III

Chapter 7 : Sexual dimorphism in the root dimensions of the comparative samples

i) Neck mesiodistal diameter

ii) Location of bifurcation

iii) Root height

iv) Root mesiodistal diameter

v) Height of bifurcation

vi) Root angulation

vii) Summary

Chapter 7 : Sexual dimorphism in the root dimensions of the comparative samples

The assessment of sexual dimorphism was based on the significance of the difference between male and female mean values, and on the value of percentage sexual dimorphism ($\varphi\bar{X}/\sigma^{\prime}\bar{X}$ x 100%). A dimension was considered to be sexually dimorphic if the male and female mean values were significantly different at the $P \leqslant 0.05$ level, with the value of percentage sexual dimorphism (%SD) indicating the degree of difference between males and females. In order to assess the contribution of sexual dimorphism to the variability of the dimensions, the male and female coefficients of variation were compared with the pooled-sex coefficient of variation.

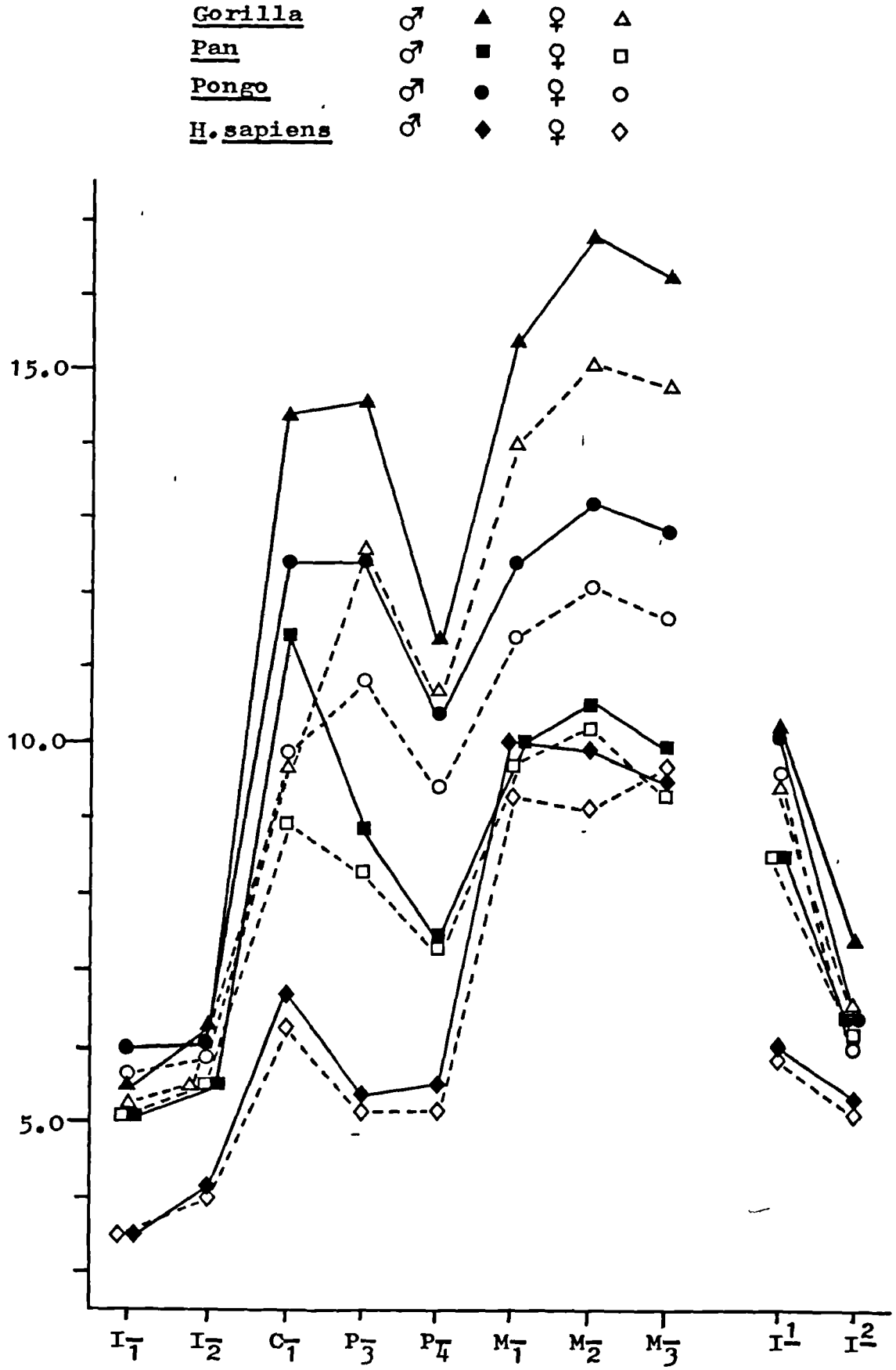
1) Neck mesiodistal diameter

Statistical summaries for neck mesiodistal diameter in the males and females of each comparative sample are given in Appendix G(1), and include the values of percentage sexual dimorphism and the significance of the difference between male and female mean values and variances. The male and female mean values of neck desiodistal diameter in the pongids and the pooled Homo sapiens sample are illustrated in Fig. 25.

Summary

Gorilla and Pongo are sexually dimorphic for most neck mesiodistal diameters, while Pan and Homo sapiens are for

Fig. 25 : Male and female mean values of neck mesiodistal diameter in the pongids and Homo sapiens



only very few diameters. However, pronounced sexual dimorphism is present in all the pongids, particularly Gorilla, for the $C_{\bar{1}}$ dimension, and this underlies the high variability of this dimension in the pooled sex samples. Moderate sexual dimorphism is present in teeth adjacent to the canine in Pongo ($P_{\bar{3}}$) and Gorilla ($I_{\bar{2}}$ $P_{\bar{3}}$ $I^{\bar{2}}$), and these pongids are also sexually dimorphic for the remaining mandibular cheek teeth. In addition to the $C_{\bar{1}}$, the only other Pan tooth which is sexually dimorphic for neck mesiodistal diameter is $M_{\bar{3}}$. Canine neck mesiodistal diameter is not sexually dimorphic in H.sapiens; only the $M_{\bar{1}}$ and $M_{\bar{2}}$ neck mesiodistal diameters are sexually dimorphic in this sample. A similar picture is seen in the Australian Aborigines, but in the Romano-British $I^{\bar{2}}$ is slightly sexually dimorphic in addition to $M_{\bar{1}}$. The high variability of some neck mesiodistal diameters in the pooled-sex comparative samples is not always explained by the presence of sexual dimorphism.

Pongids

Gorilla is sexually dimorphic to some degree for all neck mesiodistal diameters except that of $I_{\bar{1}}$. Very pronounced sexual dimorphism is present in $C_{\bar{1}}$ neck mesiodistal diameter (%SD=67%). The male and female ranges are discontinuous, and this pronounced difference between the sexes explains the very high variability of this dimension in the pooled-sex sample (C.V.: ♂+♀ =21.8, ♂=11.3, ♀=8.7). For the remaining teeth which are sexually dimorphic, i.e. the incisors (except $I_{\bar{1}}$) and all the mandibular cheek-teeth, the values of percentage sexual dimorphism range between 86% and 94% (%SD: $I_{\bar{2}}$=87%,

P_3=86%, P_4-94%, M_1=91%, M_2=90%, M_3=91%, I^1=92%, I^2=89%). The more marked sexual dimorphism in P_3 than in the rest of the mandibular cheek-teeth contributes to the higher variability of this dimension in the pooled-sex sample (C.V. P_3: ♂+♀=10.8, ♂-7.6, ♀=8.9). The high variability of the I^2 dimension in the pooled-sex sample is only slightly explained by the presence of sexual dimorphism as both sexes are also highly variable for this dimension (C.V.: ♂+♀=13.5, ♂=12.9, ♀=12.1).

All the Pongo neck mesiodistal diameters except those of the lateral incisors are sexually dimorphic to some degree. Pronounced sexual dimorphism is present in C_1 neck mesiodistal diameter (%SD=79%), but not to the same degree as in Gorilla. This underlies high variability in the pooled-sex sample, though the females are more variable than the males (C.V.: ♂+♀=15.9, ♂=7.8, ♀=14.1). Sexual dimorphism is present in all the mandibular cheek-teeth (%SD:P_3=86%, P_4=90%, M_1=92%, M_2=92%, M_3=91%), and as in Gorilla, it is more marked in P_3 than in P_4 to M_3. In addition, slight sexual dimorphism is present in the central incisor neck mesiodistal diameters (%SD:I_1=93%, I^1=94%) - dimensions which show low variability in the pooled-sex sample. However, Pongo males are more variable than the females for the I^1 dimension so that the male range completely overlaps the female (F-ratio:$P < 0.05$; C.V.: ♂+♀=9.5, ♂=10.5, ♀=5.7).

In comparison to the other pongids, sexual dimorphism is much less widespread in Pan, being found only in the C_1 and M_3 neck mesiodistal diameters. C_1 neck mesiodistal diameter

is sexually dimorphic to the same pronounced degree seen in Pongo (%SD=78%), and this underlies the high variability in the pooled-sex sample (C.V.: ♂+♀=16.1, ♂=11.3, ♀=10.5). The M_3 neck mesiodistal diameter is slightly sexually dimorphic (%SD=94%). For the incisor and M_1 and M_2 neck mesiodistal diameters, the males are more variable than the females with the result that the male ranges completely, or almost completely, overlap those of the females (F-ratio: $P<0.01$ M_2; $P<0.05$ I_2 M_1; C.V.: I_1 ♂=10.5, ♀=5.3; I_2 ♂=11.5, ♀=5.3; M_1 ♂=7.3, ♀=3.9; M_2 ♂=7.9, ♀=3.3; I^1 ♂=10.0, ♀=5.4; I^2 ♂=8.5, ♀=5.9).

Homo sapiens

In the H.sapiens sample, sexual dimorphism is present only in the M_1 and M_2 neck mesiodistal diameters (%SD: M_1=93%, M_2=92%). In the pooled sex sample, high variability is present in the lateral incisor neck mesiodistal diameters, but this results from high intra-sex variability (C.V.: I_2 ♂+♀=15.2, ♂=15.5, ♀=15.4; I^2 ♂+♀=14.6, ♂=14.0, ♀=15.3). When the Romano-British and Australian Aborigines are assessed separately, slight sexual dimorphism is present in both for the M_1 neck mesiodistal diameter (%SD: R-B=94%, A.A.=92%), but only the Australian Aborigines are sexually dimorphic for M_2 (%SD-86%). However, slight sexual dimorphism is present in the Romano-British I^2 (%SD=92%). It is worth noting that, although the male and female mean values are not significantly different, the values of percentage sexual dimorphism are less than 95% in the Australian Aborigines for I^2, C_1, P_3 and P_4 and in the Romano-British for C_1 and P_4 as the lack of significance may have resulted from small sample size.

ii) Location of bifurcation

Statistical summaries for location of bifurcation and location of bifurcation index in the males and females of each sample are given in Appendix G(ii) and H(i) respectively, and include the values of percentage sexual dimorphism and the statistical significance of the differences in male and female mean values and variances. The male and female mean values for location of bifurcation and location of bifurcation index are plotted in Figs. 26 and 27, respectively.

Summary

No clear pattern underlies the presence of sexual dimorphism in location of bifurcation. In Gorilla, Pongo and Homo sapiens, some - but not all - of the mandibular cheek-teeth which are sexually dimorphic in neck mesiodistal diameter are also sexually dimorphic in location of bifurcation. Where sexual dimorphism occurs in maxillary teeth, it does not underlie the high variability noted for the maxillary locations of bifurcation in the pooled sex samples; both sexes of the pongids and H.sapiens are generally highly variable for these dimensions. No sexual difference in the relative position of the bifurcation is present in the mandibular teeth of the pongids and H.sapiens. As in the pooled sex samples, the relative position of the bifurcation in the mandibular cheek-teeth varies little in the sexes.

Pongids

Of the Gorilla mandibular cheek-teeth, $P_{\bar{3}}$, $M_{\bar{2}}$ and $M_{\bar{3}}$ are as sexually dimorphic for location of bifurcation as they are for the corresponding neck mesiodistal diameter (%SD:$P_{\bar{3}}$=85%,

Fig. 26 : Male and female mean values for location of bifurcatio in the pongids and Homo sapiens

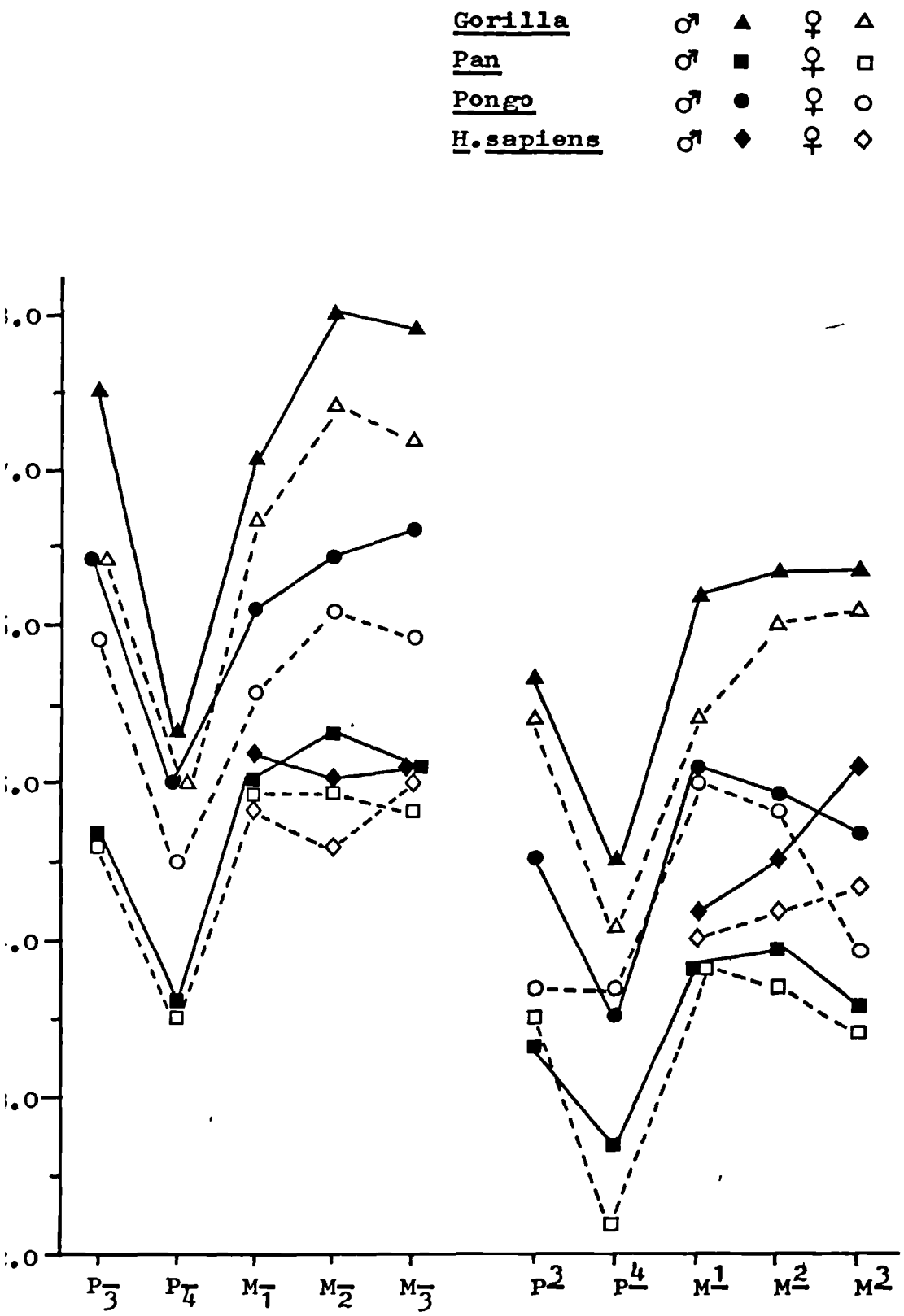
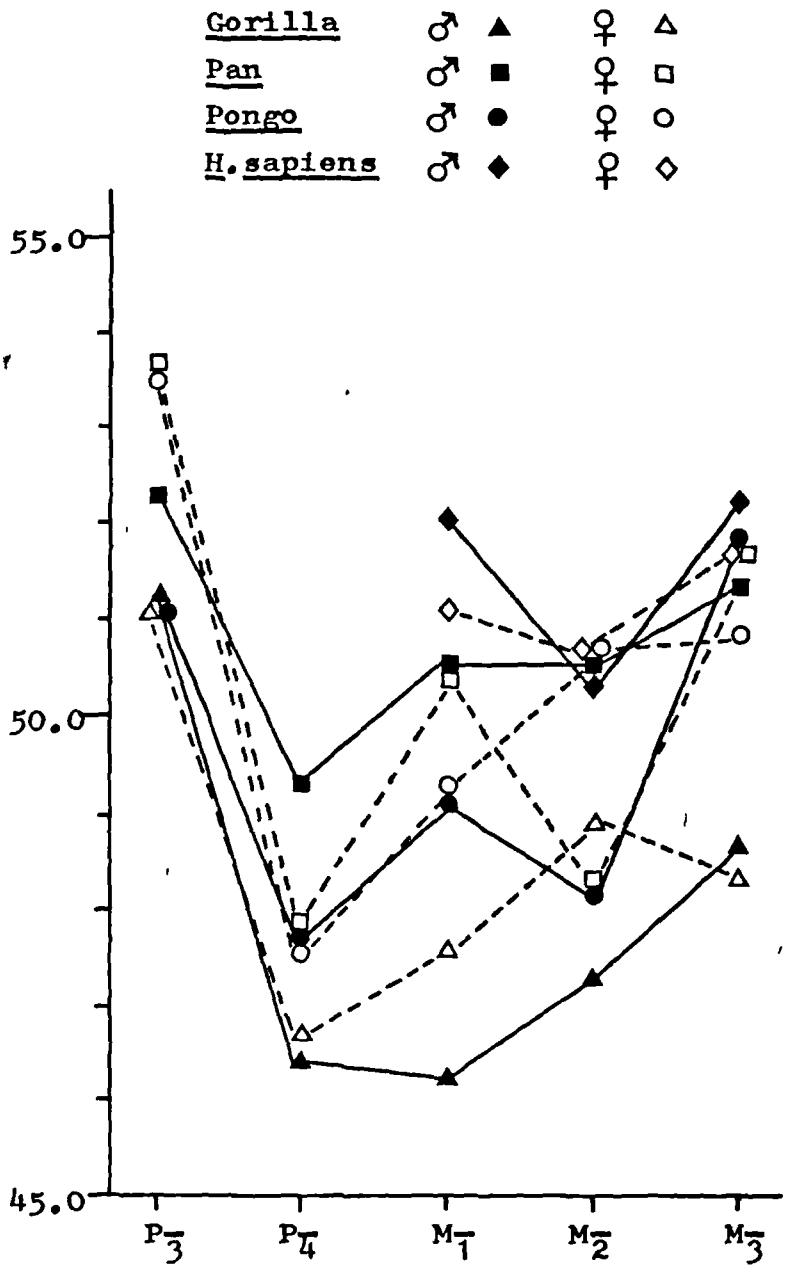


Fig. 27 : Male and female mean values for the location of bifurcation index of the mandibular teeth in the pongids and *Homo sapiens*



$M_{\overline{2}}$-93%, $M_{\overline{3}}$-91%). Of the maxillary cheek-teeth, only $M^{\underline{1}}$ is sexually dimorphic for location of bifurcation (%SD=87%), but this does not completely explain the high variability of this dimension in the pooled sex sample (C.V.: ♂+♀=14.6, ♂=13.6, ♀=12.3). Generally, both sexes are highly variable for the maxillary locations of bifurcation, as is the pooled sex sample ($\bar{X}$ C.V.: ♂+♀=14.6, ♂=15.0, ♀=12.6), and particularly for that of $P^{\underline{4}}$ (C.V.: ♂+♀=18.7, ♂=18.4, ♀=18.0). None of the Gorilla mandibular cheek-teeth shows any sexual difference in the relative position of the bifurcation.

Location of bifurcation is sexually dimorphic in Pongo for several teeth, particularly for $P^{\underline{3}}$ and $M^{\underline{3}}$ (%SD:$P_{\overline{4}}$=90%, $M_{\overline{1}}$=92%, $M_{\overline{3}}$=89%, $P^{\underline{3}}$=82%, $M^{\underline{3}}$=83%). However, the presence of sexual dimorphism in the $P^{\underline{3}}$ and $M^{\underline{3}}$ locations of bifurcation does not completely explain the high variability of these dimensions in the pooled-sex sample (C.V.:$P^{\underline{3}}$ ♂+♀=18.2, ♂=14.1, ♀-19.3; $M^{\underline{3}}$ ♂+♀=16.4, ♂=14.9, ♀=11.1). Generally, the two sexes, like the pooled-sex sample, are highly variable for the maxillary locations of bifurcation ($\bar{X}$ C.V.: ♂+♀=17.0, ♂=16.1, ♀-15.4). For $P_{\overline{4}}$, $M_{\overline{1}}$ and $M_{\overline{3}}$, the degree of sexual dimorphism is similar to that found in the corresponding neck mesiodistal diameter. None of the mandibular teeth shows sexual difference in the relative position of the bifurcation.

In Pan, only the $M_{\overline{2}}$ location of bifurcation is sexually dimorphic and slightly so (%SD=93%). The value of percentage sexual dimorphism for the $P^{\underline{4}}$ location of bifurcation is 82%, but the separate sex samples for $3RP^{\underline{4}}$ are very small and the

significance of the mean values was not tested. As in the pooled-sex sample, both sexes are generally highly variable for the maxillary locations of bifurcation ($\bar{X}$ C.V.: ♂+♀=17.5, ♂=15.0, ♀-15.0). In the mandibular cheek-teeth, there is no sexual difference in the relative position of the bifurcatio

Homo sapiens

Of the molar locations of bifurcation, the pooled Homo sapiens sample is slightly sexually dimorphic for M_1 (%SD=92%), but none of the mandibular molars shows sexual difference in the location of bifurcation index. When the H.sapiens subsamples are assessed separately, only the Romano-British are sexually dimorphic for the M_1 location of bifurcation (%SD=88%) In contrast, the Australian Aborigines are sexually dimorphic for the M_1 location of bifurcation (%SD=86%).

iii) Root height

Statistical summaries for actual root height and projected root height in the males and females of each comparative sample are given in Appendices G(iii) and G(iv), respectively, and include the values of percentage sexual dimorphism and the significance of the differences in male and female mean values and variances. The male and female mean values of actual root height in the pongids and pooled Homo sapiens sample are plotted in Fig. 28 for the mandibular dentition, and Fig. 29 for the maxillary.

Summary

Many root heights are sexually dimorphic in Gorilla and Pongo, particularly in the mandibular dentition. Gorilla is

Fig. 28 : Male and female mean values of mandibular actual root height in the pongids and Homo sapiens

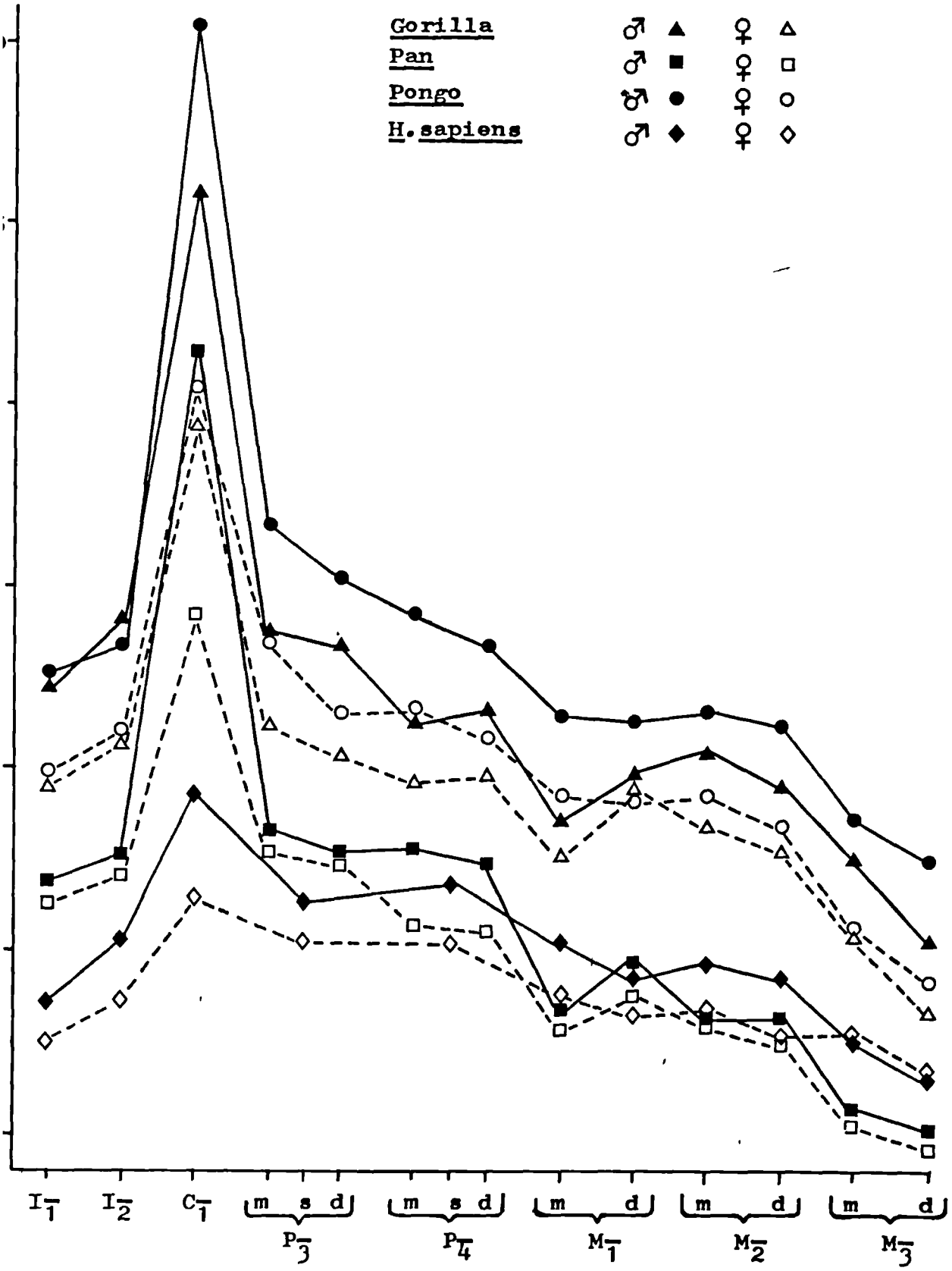
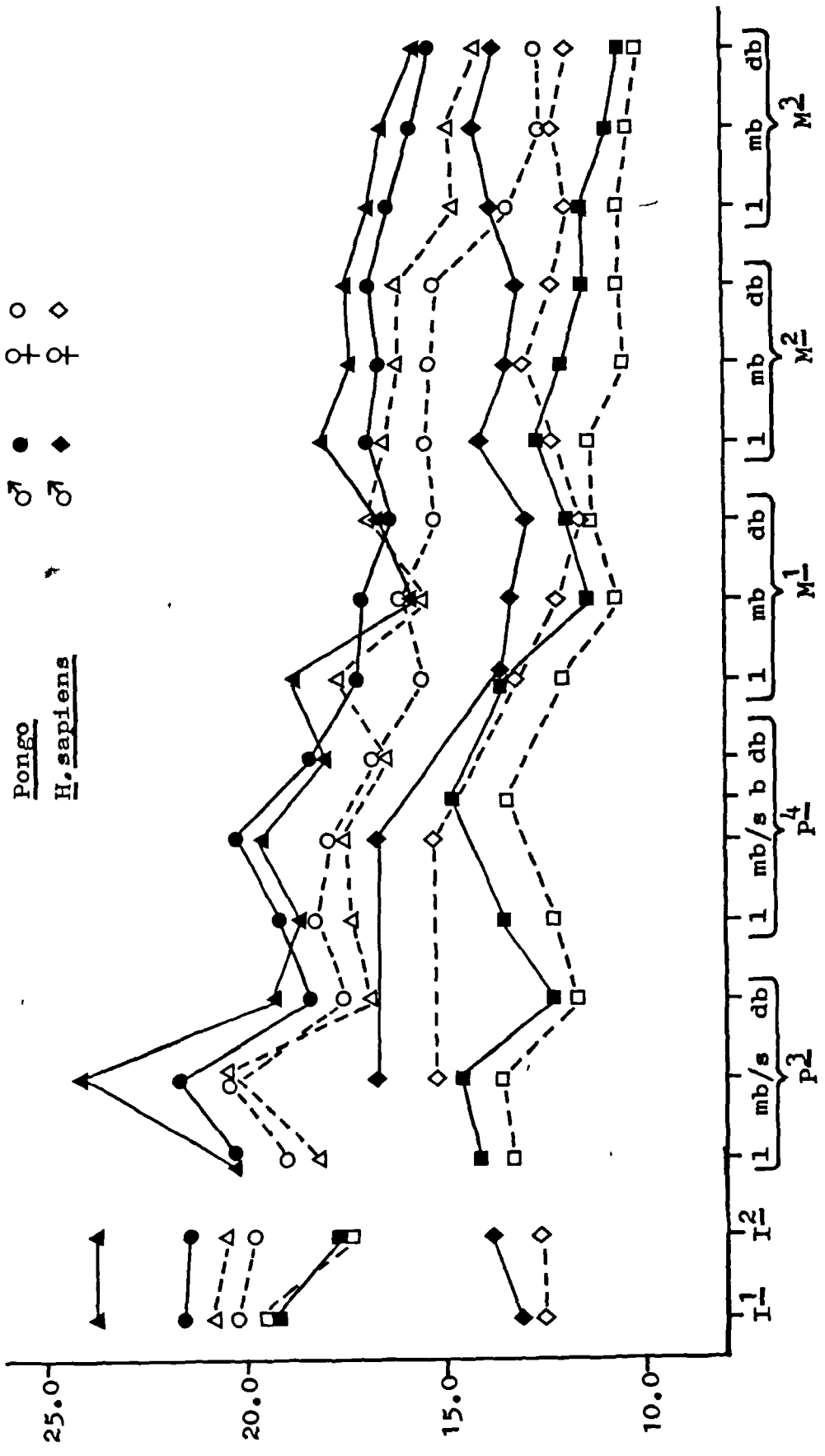


Fig. 29 : Male and female mean values of maxillary actual root height in the pongids and Homo sapiens



sexually dimorphic for the anterior roots extending into third premolar roots, for most mandibular postcanine roots and most maxillary lingual roots. No first molar root heights are sexually dimorphic in Gorilla. Pongo is sexually dimorphic for all mandibular root heights, the $M_{\overline{1}}$ lingual root height and all $M_{\overline{3}}$ root heights. In comparison, Pan and Homo sapiens are sexually dimorphic for few root heights. $C_{\overline{1}}$ root height is sexually dimorphic in all the pongids and H.sapiens, and this explains, at least in part, the high variability of this dimension in the pooled-sex samples. In addition, $P_{\overline{4}}$ root height is slightly sexually dimorphic in the pongids and H.sapiens. In the maxillary dentition, sexual dimorphism most frequently occurs in the lingual roots. In the pooled-sex pongid samples, maxillary buccal root heights are generally highly variable; this high variability is also generally present in the separate sexes so that male and female ranges overlap considerably. In Gorilla, incisor and third molar root heights are more variable in males than females, while Pongo females are more variable than males for premolar and some other roots. With the exception of $C_{\overline{1}}$ root height, sexual dimorphism does not explain the high variability of some root heights in the pooled-sex H.sapiens sample. In contrast to the virtual absence of sexual dimorphism in the Romano-British, many root heights are sexually dimorphic in the Australian Aborigines.

Pongids

Many root heights are sexually dimorphic in Gorilla, particularly in the mandibular dentition. The most clear-cut

sexual difference is shown by $C_{\bar{1}}$ root height (%SD=82%) for which the male and female ranges are nearly discontinuous. This dimension varies little within the sexes and so the higher variability in the pooled-sex sample reflects the sexual dimorphism of this dimension (C.V.: ♂+♀ =12.5, ♂=7.9, ♀=7.4). Otherwise, sexual dimorphism is present in many roots - with the notable exceptions of the $M_{\bar{1}}$ roots and most maxillary buccal roots - and is generally most marked in the incisor, third premolar and third molar roots (%SD: $I_{\bar{1}}$=88%, $I_{\bar{2}}$=87%, $P_{\bar{3}}$m-89%, $P_{\bar{3}}$d=87%, $P_{\bar{4}}$m=93%, $P_{\bar{4}}$d=93%, $M_{\bar{2}}$m=90%, $M_{\bar{2}}$d=91%, $M_{\bar{3}}$m=87%, $M_{\bar{3}}$d=87%, $I^{\bar{1}}$=88%, $I^{\bar{2}}$=87%, $P^{\bar{3}}$mb=86%, $P^{\bar{3}}$l=90%, $P^{\bar{4}}$l=92%, $M^{\bar{2}}$l=93%, $M^{\bar{3}}$l-88%). However, for many incisor and mandibular molar roots, the males are more variable than the females with the effect that these roots are similarly short in individuals of both sexes, but are particularly long only in males. (F-ratio: $P < 0.001$ $M_{\bar{2}}$d; $P < 0.01$ $M_{\bar{1}}$d $M_{\bar{2}}$m $M_{\bar{3}}$m $M_{\bar{3}}$d $I^{\bar{1}}$; $P < 0.05$ $I_{\bar{1}}$ $I_{\bar{2}}$; C.V.: $I_{\bar{1}}$ ♂=12.9, ♀=7.2; $I_{\bar{2}}$ ♂=9.0, ♀=6.0; $M_{\bar{1}}$d ♂=14.1, ♀=7.3; $M_{\bar{2}}$m ♂=12.2, ♀-6.9; $M_{\bar{2}}$d ♂=14.5, ♀=5.9; $M_{\bar{3}}$m ♂=14.1, ♀-7.7, $M_{\bar{3}}$d ♂=16.8, ♀=8.7, $I^{\bar{1}}$ ♂=13.8, ♀=7.2). For this reason, the high variability of the $M_{\bar{3}}$ distal root in the pooled-sex sample stems particularly from high male variability (C.V.: ♂+♀ =15.9, ♂-16.8, ♀=8.7). Although the $P^{\bar{3}}$ mesiobuccal and lingual roots are sexually dimorphic in Gorilla, this does not explain the high variability of these dimensions in the pooled-sex sample (C.V.: $P^{\bar{3}}$mb ♂+♀ =18.6, ♂=17.4, ♀-16.5; $P^{\bar{3}}$l ♂+♀ =15.1, ♂=14.0, ♀=14.6); both males and females are highly variable for these dimensions and their ranges overlap considerably. In fact, all the maxillary buccal root heights are highly variable in both males and females, as in the pooled-sex sample ($\bar{X}$ C.V.: ♂+♀ =18.0,

♂=17.6, ♀=17.1), and this is reflected in the lack of significant difference between the male and female mean values, with the exception of the lingual and mesiobuccal roots of P^3, even though the value of percentage sexual dimorphism is less than 95% in most of them.

Root height is sexually dimorphic in Pongo for many roots, particularly for mandibular roots as in Gorilla. Pronounced sexual dimorphism is found in $C_{\bar{1}}$ root height (%SD=75%) and for this dimension the male and female ranges are very nearly discontinuous. This pronounced between-sex difference partly explains the high variability of $C_{\bar{1}}$ root height in the pooled sex sample, though Pongo females are also highly variable and more variable than the males (C.V.: ♂+♀=19.4, ♂=9.8, ♀=15.9). All M^3 root heights are quite markedly sexually dimorphic (%SD: M^3mb=79%, M^3l=82%, M^3db=83%) - and this partly explains the high variability noted in the pooled-sex sample (C.V.: M^3l ♂+♀=15.4, ♂=11.7, ♀=11.4; M^3mb ♂+♀=16.5, ♂=11.0, ♀=13.3; M^3db ♂+♀=17.8, ♂=15.4, ♀=14.4). In addition to $C_{\bar{1}}$ root height, all other Pongo mandibular root heights are sexually dimorphic, particularly the $M_{\bar{3}}$ root heights (%SD: $I_{\bar{1}}$=88%, $I_{\bar{2}}$=90%, $P_{\bar{3}}$m=88%, $P_{\bar{3}}$d=85%, $P_{\bar{4}}$m=89%, $P_{\bar{4}}$d=90%, $M_{\bar{1}}$m=89%, $M_{\bar{1}}$d=90%, $M_{\bar{2}}$m=89%, $M_{\bar{2}}$d=87%, $M_{\bar{3}}$m=83%, $M_{\bar{3}}$d=81%). However, for the $P_{\bar{3}}$, $P_{\bar{4}}$ and $M_{\bar{2}}$ roots the female ranges completely overlap the male ranges as the females are highly variable for these root heights (C.V. $P_{\bar{3}}$m ♂=9.2, ♀=16.7; $P_{\bar{3}}$d ♂=11.6, ♀=18.3; $P_{\bar{4}}$m ♂=11.8, ♀=18.5; $P_{\bar{4}}$d ♂=10.5, ♀=18.5; $M_{\bar{2}}$m ♂=11.5, ♀=15.7; $M_{\bar{2}}$d ♂=12.2, ♀-19.2). This high variability in the females underlies the generally high variability noted in the pooled-sex samples for these roots (C.V. ♂+♀ : $P_{\bar{3}}$m=13.7,

P_3d=16.3, P_4m=15.9, P_4d=15.1, M_2m=14.4, M_2d=16.7). However, the high variability of M_3 distal root height stems mainly from the males (C.V.: ♂+♀=18.4, ♂=16.8, ♀=10.8). Apart from the M^3 roots already described, the only other maxillary root height which is sexually dimorphic is that of the M^1 lingual root (%SD=91%). In the pooled-sex sample, most maxillary buccal roots and some maxillary lingual roots are highly variable. In the premolars, this stems mainly from high variability in the females, while in M^1 and M^2 it stems from high variability in both sexes. For most maxillary premolar, and also incisor, roots, the female ranges completely overlap the male ranges, as already noted for the mandibular premolars and M_2.

In comparison to the other pongids, Pan exhibits little sexual dimorphism in root height. C_1 root height is sexually dimorphic to the same pronounced degree seen in Pongo (%SD=76%) but the male and female ranges overlap more in Pan than in the other pongids. However, the between-sex difference explains the high variability noted for this dimension in the pooled-sex sample (C.V.: ♂+♀=16.2, ♂=8.7, ♀=11.4). Apart from the canine, sexual dimorphism is present only in the root heights of P_4 and the lingual roots of $2RP^4$, M^1 and M^2 (%SD: P_4m=89%, P_4d=90%, $2RP^4$l=89%, M^1l=88%, M^2l=89%). However, the male range completely overlaps the female for M^1 lingual root height. The values of percentage sexual dimorphism for the $3RP^4$ root heights are considerably less than 95% (%SD: $3RP^4$l=83%, $3RP^4$mb=78%, $3RP^4$db=84%), but the separate sex samples are very small and the significance of the male and female mean values was not tested. The high variability noted for maxillary buccal root heights in the

pooled-sex sample is also generally found in the separate sexes ($\bar{X}$ C.V.: ♂+♀ =16.4, ♂=16.6, ♀=15.4).

Homo sapiens

In the Homo sapiens sample, root height is sexually dimorphic for the $C_{\bar{1}}$ and $P_{\bar{4}}$, and for roots of the first and second molars. $C_{\bar{1}}$ root height is moderately sexually dimorphic (%SD=86%), but the male and female ranges overlap more than in the pongids. The high variability of $C_{\bar{1}}$ root height in the pooled-sex sample is found also in the males (C.V.: ♂+♀ =16.4, ♂=16.7, ♀=12.4). Sexual dimorphism is present also in the $M^{\bar{1}}$ buccal and $M^{\bar{2}}$ lingual root heights and in the $P_{\bar{4}}$, $M_{\bar{1}}$ and $M_{\bar{2}}$ root heights (%SD:$P_{\bar{4}}$=90%, $M_{\bar{1}}$m=91%, $M_{\bar{1}}$d=93%, $M_{\bar{2}}$m=90%, $M_{\bar{2}}$d=90%, $M^{\bar{1}}$mb=90%, $M^{\bar{1}}$db=90%, $M^{\bar{2}}$l=88%). The $I^{\bar{2}}$, $P^{\bar{3}}$, $P^{\bar{4}}$ and $M^{\bar{3}}$ root heights are highly variable in the pooled-sex sample; these dimensions are also generally highly variable in the separate sexes though $I^{\bar{2}}$ root height is more variable in males than females (F-ratio:$P < 0.05$; C.V.: ♂=19.6, ♀ =12.2).

When the H.sapiens subsamples are assessed separately, both are sexually dimorphic for $M^{\bar{1}}$ mesiobuccal root height (%SD:R-B=89%, A.A.=88%), but this is the only root height which is sexually dimorphic in the Romano-British, while the Australian Aborigines are moderately sexually dimorphic for several more (%SD:$C_{\bar{1}}$=80%, $P_{\bar{4}}$=86%, $M_{\bar{1}}$m=88%, $M_{\bar{2}}$m=85%, $M_{\bar{2}}$d=85%, $I^{\bar{2}}$=81%, $P^{\bar{3}}$=83%, $M^{\bar{1}}$db=87%, $M^{\bar{2}}$l=80%).

iv) Root mesiodistal diameter

Statistical summaries for root mesiodistal diameter

and root robusticity index in the sexes of the comparative samples are given in Appendices G(v) and H(ii), respectively, and include the values of percentage sexual dimorphism and the statistical significance of the differences in male and female mean values and variances. The male and female mean values for root mesiodistal diameter are plotted out in Figs. 30 and 31, and those for the root robusticity index in Figs. 32 and 33.

Summary

In the pongids and Homo sapiens, the generally high variability of root mesiodistal diameter in the pooled-sex samples is present also in the separate sexes. The particularly high variation of certain root mesiodistal diameters in the pooled-sex samples is not usually explained by the presence of sexual dimorphism, with the notable exception of the $C_{\bar{1}}$ dimension in the pongids. $C_{\bar{1}}$ root mesiodistal diameter is sexually dimorphic to a pronounced degree in all the pongids and this underlies the high variability of this dimension in the pooled-sex samples. This dimension is not sexually dimorphic in H.sapiens. Gorilla and Pongo are sexually dimorphic for more root mesiodistal diameters than either Pan or H.sapiens. In addition to the $C_{\bar{1}}$ root, Gorilla and Pongo are sexually dimorphic for the $P_{\bar{3}}$ roots and the $M_{\bar{1}}$ distal root; otherwise, the $M_{\bar{2}}$ distal root and maxillary molar roots are sexually dimorphic in Gorilla, while some premolar roots and the $M_{\bar{1}}$ roots are sexually dimorphic in Pongo. In common with the other pongids, Pan is sexually dimorphic for the $M_{\bar{1}}$ distal root. Root mesiodistal diameter is sexually dimorphic in H.sapiens for the P^3 root

Fig. 30 : Male and female mean values of mandibular root mesiodistal diameter in the pongids and Homo sapiens

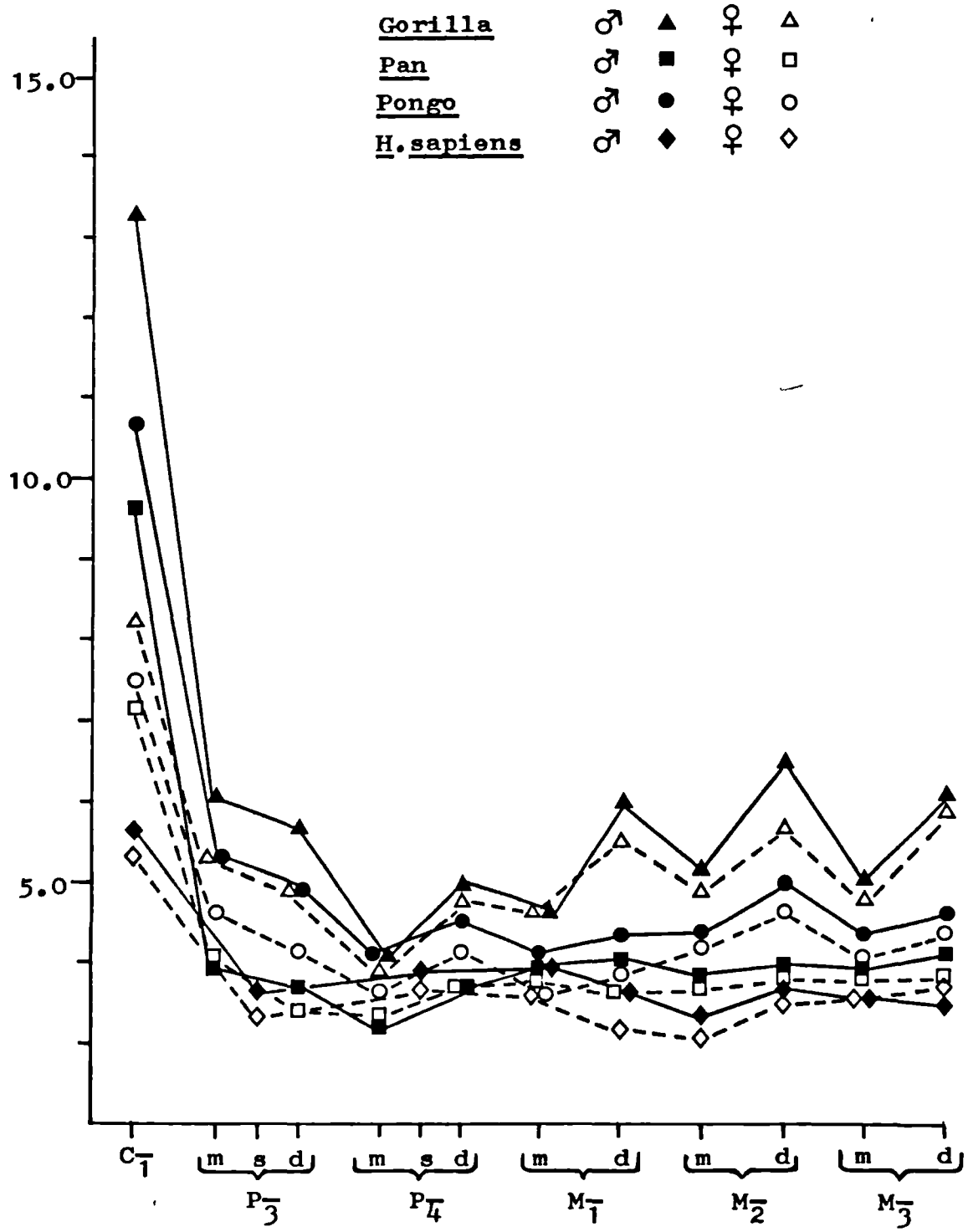


Fig. 31 : Male and female mean values of maxillary root mesiodistal diameter in the pongids and Homo sapiens

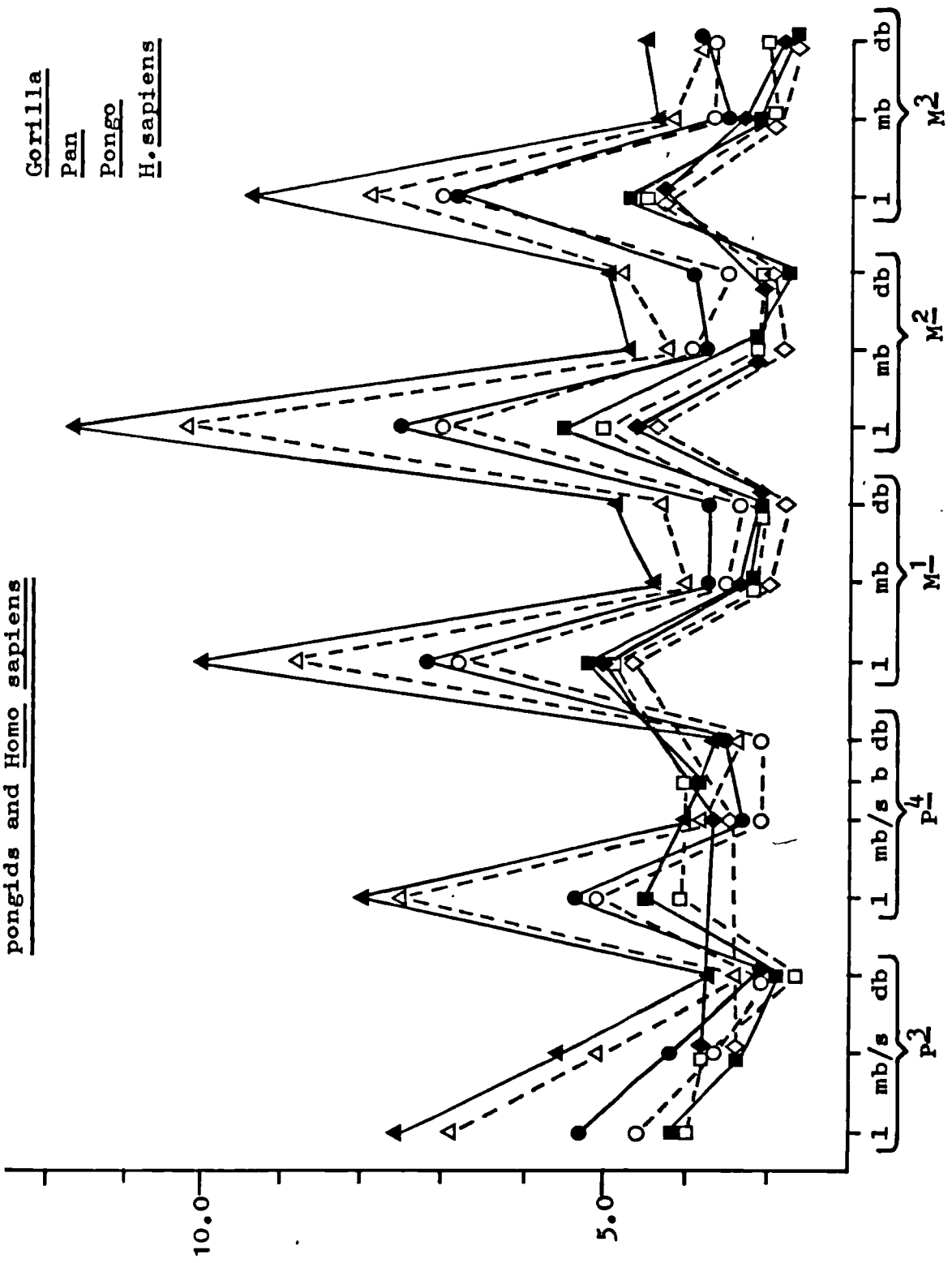
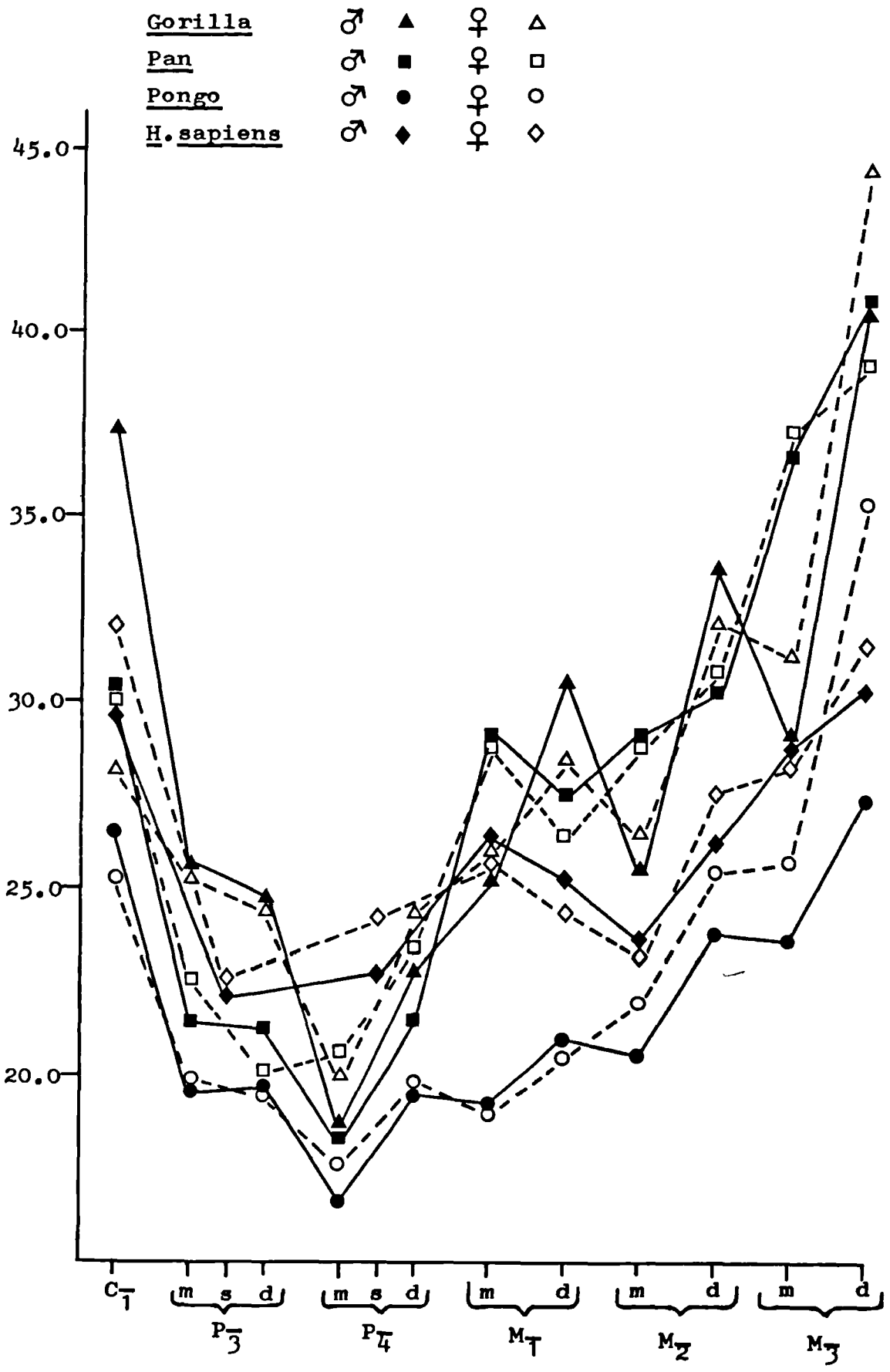
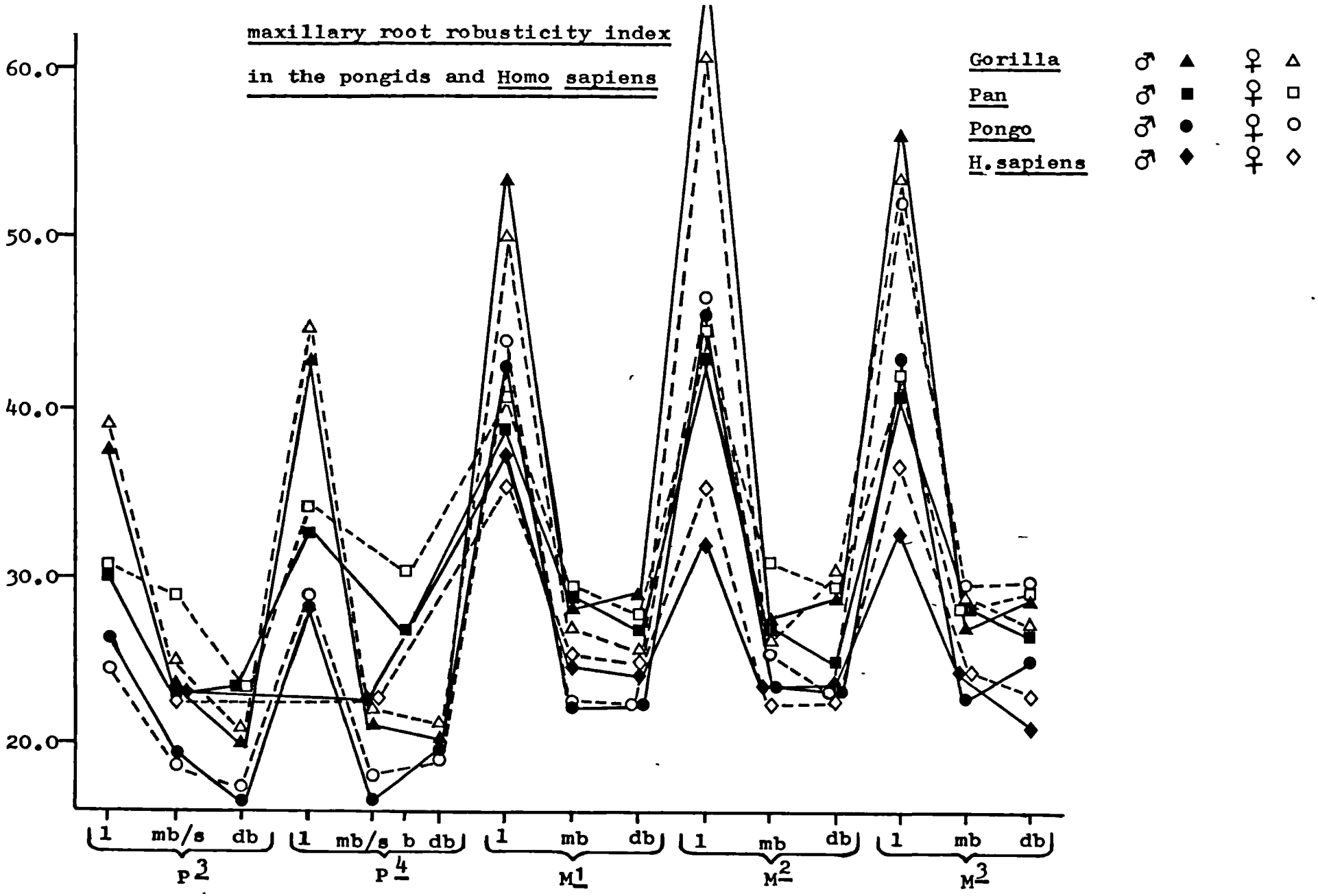


Fig. 32 : Male and female mean values of mandibular root robusticity index in the pongids and Homo sapiens




maxillary root robusticity index
in the pongids and Homo sapiens
Gorilla
Pan
Pongo
H.sapiens
♂ ♀
60.0
50.0
40.0
30.0
20.0
l mb/s db
P3
l mb/s b db
P4
l mb db
M1
l mb db
M2
l mb db
M3

and some molar roots including the M_1 distal root.

No clear pattern underlies sexual differences in root robusticity. Each of the pongids and H.sapiens are sexually dimorphic for a few roots; however, where sexual difference occurs in Gorilla, males have the more robust roots, while in the others, females do. As in the pooled-sex samples, root robusticity is generally highly variable in the separate sexes.

Pongids

In Gorilla, the C_1, P_3 and some molar roots are sexually dimorphic for root mesiodistal diameter. Pronounced sexual dimorphism is present in C_1 root mesiodistal diameter (%SD= 62%); the male and female ranges are discontinuous and this marked sexual difference underlies the very high variation in the pooled-sex sample, though both sexes are highly variabl for this dimension (C.V.: ♂+♀ =26.8, ♂=14.4, ♀=12.1). Sexual dimorphism is also found in the P_3 roots, the distal roots of M_1 and M_2, the maxillary molar lingual roots, the disto-buccal roots of M^1 and M^2 and the M^2 mesiobuccal root (%SD: P_3m-87%, P_3d=86%, M_1d-92%, M_2d=88%, M^1l=88%, M^1db=90%, M^2l=87% M^2mb-89%, M^3l=84%, M^3db=84%). Overall, the presence of sexual dimorphism does not explain the generally high variabil of root mesiodistal diameter in the pooled-sex sample; in fact, some roots which are sexually dimorphic - the distal roots of M_1 and M_2 and the M^1 lingual root - are comparatively less variable in the pooled-sex sample than roots which are not sexually dimorphic. For most of the sexually dimorphic maxillary molar roots, the male and female ranges overlap very

considerably and the high variability noted in the pooled-sex sample is also present in one or both of the separate sexes. One or both sexes are also particularly highly variable for the mesiodistal diameters of the mesial roots of $M_{\bar{1}}$ and $M_{\bar{2}}$, the $P^{\underline{3}}$ lingual root and all maxillary mesiobuccal roots - dimensions which are also generally particularly highly variable in the pooled-sex sample; with the exception of the $M^{\underline{2}}$ mesiobuccal root, none of these dimensions is sexually dimorphic. In Gorilla, the $C_{\bar{1}}$ is sexually dimorphic for root height and root mesiodistal diameter, as it is for root robusticity (%SD-76%). Only the upper part of the female range overlaps the lower part of the male range, but this sexual difference only partly explains the high variability in the pooled-sex sample; the upper part of the male range is very extensive indicating that some male gorillas have very robust $C_{\bar{1}}$ roots (C.V.: ♂+♀=21.8, ♂=18.2, ♀=13.5). In addition, the $M^{\underline{1}}$ distobuccal root is moderately more robust in males than females (%SD=88%). The robusticity of the roots is generally highly variable in the pooled-sex sample, so it is also in the separate sexes ($\bar{X}$ C.V.: ♂+♀=17.2, ♂=16.7, ♀=16.8).

Root mesiodistal diameter is sexually dimorphic in Pongo for the $C_{\bar{1}}$ root, premolar roots and the roots of $M_{\bar{1}}$. $C_{\bar{1}}$ root mesiodistal diameter is sexually dimorphic to a pronounced degree (%SD=70%) as in Gorilla, and the male and female ranges are discontinuous which underlies the high variability in the pooled-sex sample (C.V.: ♂+♀=20.6, ♂=8.6, ♀=8.3). Sexual dimorphism is also present in roots of $P_{\bar{3}}$, $P_{\bar{4}}$ and $M_{\bar{1}}$ and in the $P^{\underline{3}}$ lingual root and $P^{\underline{4}}$ distobuccal root (%SD: $P_{\bar{3}}$m=87%, $P_{\bar{3}}$d=84%, $P_{\bar{4}}$d=91%, $M_{\bar{1}}$m-88%, $M_{\bar{1}}$d=89%, $P^{\underline{3}}$l=87%, $P^{\underline{4}}$db=89%). The

particularly high variability of some of these root mesiodistal diameters in the pooled-sex sample - the roots of P_3 and the M_1 mesial root - is also found in the males (C.V. ♂+♀: P_3m=15.6, P_3d=15.5, M_1m-15.0; ♂: P_3m-15.2, P_3d=14.1, M_1m=15.6; ♀: P_3m=12.9, P_3d-10.6, M_1m=10.2). Other root mesiodistal diameters are also particularly highly variable in the males, being more variable than in females (C.V. P^4mb ♂+♀=13.0, ♂=15.0, ♀=8.1; M^1db ♂+♀=15.8, ♂=17.4, ♀=11.5; M^3db ♂+♀=12.8, ♂=16.3, ♀=7.8). However, the high variability observed for some root mesiodistal diameters in the pooled-sex sample is also present in both sexes (C.V.: M_2m ♂+♀=17.1, ♂=16.6, ♀=18.0; M_3d ♂+♀=16.8, ♂=16.9, ♀=17.3; P^3mb ♂+♀=19.4, ♂=18.8, ♀=18.8; M^3db ♂+♀=16.9, ♂=19.2, ♀=14.6). Pongo females have more robust M^3 lingual and, particularly, M^3 mesiobuccal roots than males (%SD: M^3l=122%, M^3mb=131%). The high variability of root robusticity in the pooled-sex sample is present also in the separate sexes (X C.V: ♂+♀ = 19.0, ♂=18.8, ♀=18.3).

As in the other pongids, C_1 root mesiodistal diameter is sexually dimorphic in Pan (%SD=75%) and this sexual difference partly underlies the high variability in the pooled-sex sample, though this dimension is also highly variable in the females (C.V.: ♂+♀=17.8, ♂=9.0, ♀=15.5). Apart from the C_1 root, the M_1 distal root is slightly sexually dimorphic in Pan (%SD=90%); this dimension varies little either within the sexes or in the pooled-sex sample (C.V.: ♂+♀=10.1, ♂=9.2, ♀=8.6). In general, root mesiodistal diameter is highly variable in the pooled-sex sample, and it

is also in the separate sexes ($\bar{X}$ C.V.: ♂+♀ =14.0, ♂=14.1, ♀ -12.5), being slightly more variable in the maxillary cheek-teeth (C.V.: ♂+♀ =14.8, ♂=15.4 ♀=13.1) than in the mandibular (C.V.: ♂+ ♀-12.5, ♂=12.8, ♀=11.3). In comparison to the males, Pan females have more robust P_4 mesial, M^2 buccal and, particularly, P^3 mesiobuccal roots (%SD:P_4m=113%, P^3mb=123%, M^2mb=117%, M^2db=117%). However, for the P_4 mesial and M^2 distobuccal roots the male and female ranges overlap considerably reflecting particularly high variability in one or both of them. The robusticity of the roots is generally highly variable in the pooled-sex sample, and it is also in the separate sexes ($\bar{X}$ C.V.: ♂+♀ =16.1, ♂=16.1, ♀ =15.3).

Homo sapiens

Homo sapiens is sexually dimorphic for the root mesiodistal diameters of the M_1 distal and M_2 mesial roots and of the P^3 and M^1 distobuccal roots (%SD:M_1d=89%, M_2m=91%, P^3=90%, M^1db=90%). However, the male and female ranges for the P^3 and M^1 distobuccal dimensions overlap considerably. In general, root mesiodistal diameter is highly variable in the pooled-sex sample ($\bar{X}$ C.V.=15.0); some root mesiodistal diameters are particularly highly variable, but none of these is sexually dimorphic. The males and females are also generally highly variable for this dimension ($\bar{X}$ C.V.: ♂=14.6, ♀=14.4). As in the pooled-sex sample, the robusticity of the roots is generally highly variable also in the separate sexes ($\bar{X}$ C.V.: ♂+♀ =15.2, ♂=15.2, ♀ =15.2). Root robusticity is sexually dimorphic only for the M^2 lingual root, which is more robust in the females (%SD=112%).

When the H.sapiens subsamples are assessed separately, root mesiodistal diameter is sexually dimorphic in the Romano-British only for the $M^{\overline{2}}$ mesiobuccal root (%SD=84%), but in the Australian Aborigines it is for the mandibular molar mesial roots and the $M_{\overline{1}}$ distal root (%SD:$M_{\overline{1}}$m=90%, $M_{\overline{1}}$d-82%, $M_{\overline{2}}$m=84%, $M_{\overline{3}}$m-83%). However, in both groups the value of percentage sexual dimorphism is less than 95% for several roots and for some of these the lack of significant difference between the male and female mean values may have resulted from small sample size, though the generally high variability of root mesiodistal diameter may also have played a part.

v) Height of bifurcation

Statistical summaries for height of bifurcation and height of bifurcation index in the sexes are given in Appendices G(vi) and H(iii), respectively, and include the values of percentage sexual dimorphism and the statistical significance of the differences in male and female mean values and variances. The male and female mean values of height of bifurcation and height of bifurcation index in the pongids and Homo sapiens are plotted in Figs. 34 and 35, respectively.

Summary

As in the pooled-sex samples, height of bifurcation and the height of bifurcation index are very variable in both sexes of the pongids and H.sapiens. The male and female ranges generally overlap considerably, even when sexual

Fig. 34 : Male and female mean values for height of bifurcation in the pongids and Homo sapiens

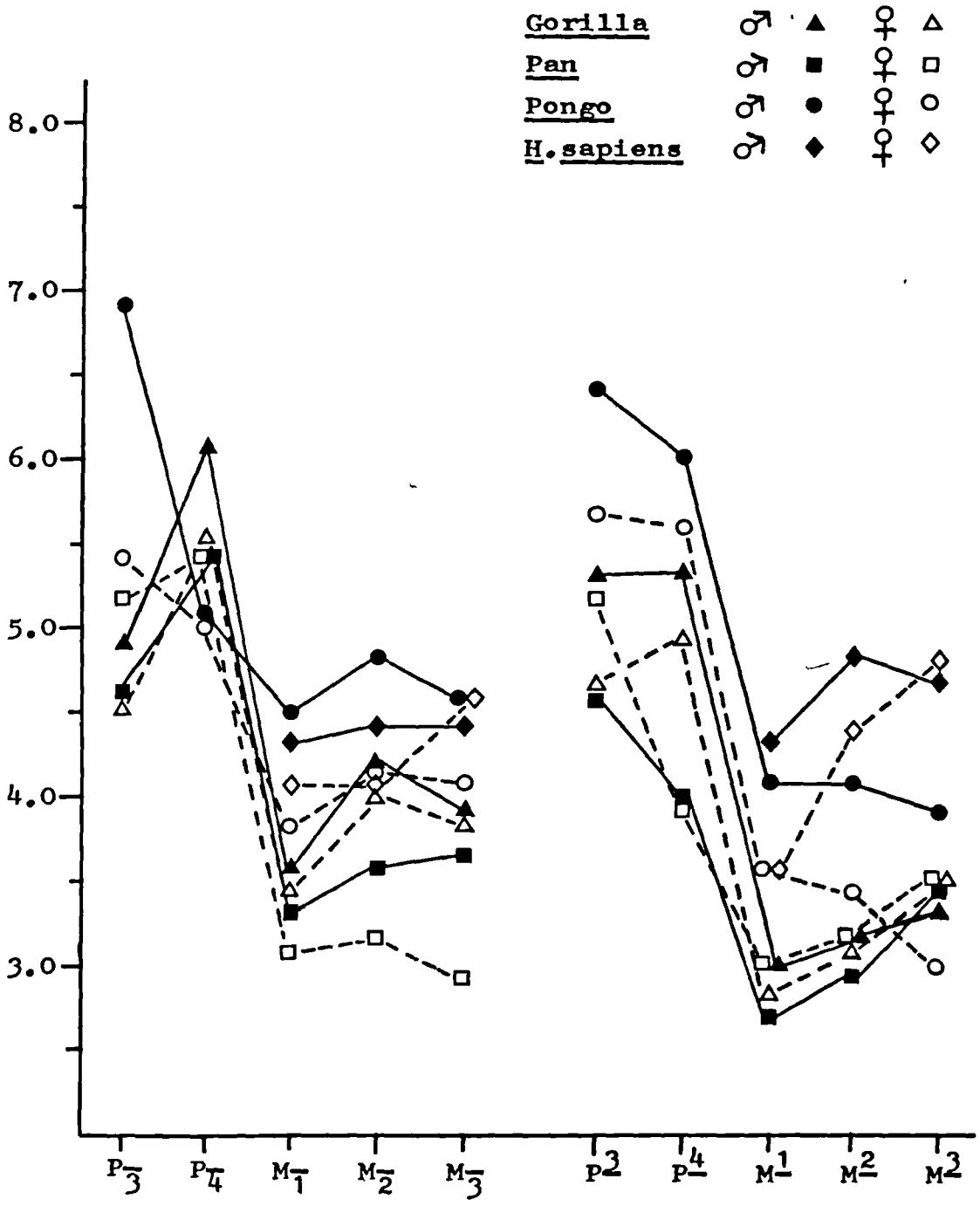
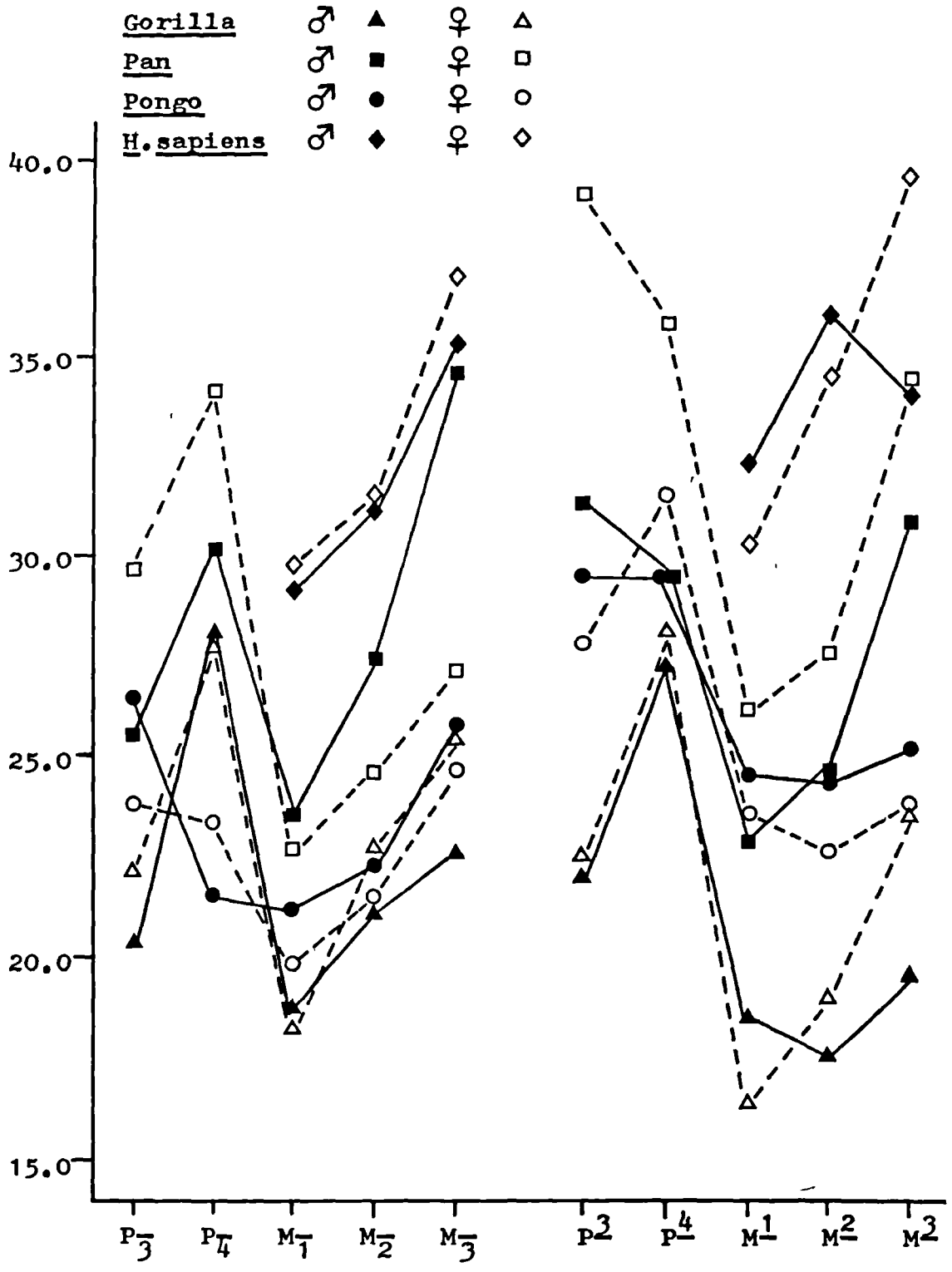


Fig. 35 : Male and female mean values for the height of bifurcation index in the pongids and Homo sapiens



dimorphism is indicated by significant difference in male and female mean values. and even when this difference is marked. Height of bifurcation is not sexually dimorphic in Gorilla, but is so in Pan and Pongo for a few mandibular teeth. The $M_{\bar{1}}$ height of bifurcation is sexually dimorphic in H.sapiens. Only in Pan is there sexual difference in the relative height of bifurcation - for $P^{\bar{3}}$ and $M_{\bar{3}}$.

Pongids

Sexual dimorphism is not present in the Gorilla heights of bifurcation. Thus, sexual dimorphism does not underlie the very high variation of height of bifurcation in the pooled-sex sample, and each sex is also highly variable ($\bar{X}$ C.V.: ♂+♀=29.8, ♂=30.4, ♀=28.7). Nor is there any sexual difference in relative height of bifurcation in Gorilla. As in the pooled-sex sample, height of bifurcation index is very variable in the sexes ($\bar{X}$ C.V.: ♂+♀=28.5, ♂=29.3, ♀=26.7).

The $P_{\bar{3}}$, $M_{\bar{1}}$ and $M_{\bar{2}}$ heights of bifurcation are sexually dimorphic in Pongo (%SD:$P_{\bar{3}}$=78%, $M_{\bar{1}}$=84%, $M_{\bar{2}}$=88%), but the male and female ranges overlap considerably. Both sexes are highly variable for these dimensions, as they are generally for height of bifurcation ($\bar{X}$ C.V.: ♂=26.2, ♀=22.8). Thus, sexual dimorphism does not explain the high variability of height of bifurcation in the pooled-sex sample ($\bar{X}$ C.V.=26.1). Relative height of bifurcation is not sexually dimorphic in Pongo. The height of bifurcation index is highly variable in the sexes, as in the pooled-sex sample ($\bar{X}$ C.V.: ♂+♀=22.8, ♂-24.6, ♀=20.1).

Height of bifurcation is sexually dimorphic in Pan for $M_{\overline{2}}$ and $M_{\overline{3}}$ (%SD:$M_{\overline{2}}$=89%, $M_{\overline{3}}$=78%), but for the $M_{\overline{2}}$ dimension, the males are more variable than the females, and the male range completely overlaps the female (F-ratio:P=0.001; C.V.: ♂=22.7, ♀-8.3). Generally, the females are as highly variable as the males, and the separate sexes show the same high variation as the pooled-sex sample ($\bar{X}$ C.V.: ♂+♀=29.1, ♂=27.6, ♀=28.0). Pan is also sexually dimorphic for the relative height of the $M_{\overline{3}}$ bifurcation, this being greater in the males (%SD=78%). On the contrary, the relative height of the $P^{\overline{3}}$ bifurcation is greater in females (%SD=125%). Both sexes are generally highly variable for the height of bifurcation index, as is the pooled-sex sample ($\bar{X}$ C.V.: ♂+♀ = 27.1, ♂=25.3, ♀-26.5).

Homo sapiens

The $M^{\overline{1}}$ height of bifurcation is sexually dimorphic in H.sapiens (%SD=84%), but the male and female ranges overlap very considerably. The pooled-sex sample is highly variable for this dimension, and so too are the separate sexes ($\bar{X}$ C.V.: ♂+♀=20.4, ♂=20.7, ♀=19.3). No sexual difference in relative height of bifurcation is present in H.sapiens. The height of bifurcation index is highly variable in both sexes, as in the pooled-sex sample ($\bar{X}$ C.V.: ♂+♀=19.4, ♂=18.3, ♀=17.5).

When the H.sapiens subsamples are assessed separately, none of the molar heights of bifurcation is sexually dimorphic in the Romano-British, but those of $M_{\overline{1}}$ and $M_{\overline{2}}$ are in the Australian Aborigines (%SD: $M_{\overline{1}}$=87%, $M_{\overline{2}}$=83%). As in the pooled-sex samples, this dimension is highly variable in the

sexes of both groups (X C.V.:R-B ♂+♀ =20.3, ♂=20.8, ♀ =18.3; A.A. ♂+♀ =18.4, ♂=16.8, ♀=16.8).

vi) Root angulation

Statistical summaries for root angulation and root divergence in the sexes of the comparative samples are given in Appendices G(vii) and H(iv), respectively, and include the statistical significance of the differences in male and female mean values and variances. Percentage sexual dimorphism and the coefficient of variation were not calculated for these dimensions. The male and female mean values of root angulation in the pongids and H.sapiens are plotted in Figs. 36 and 37, and those for root divergence in Fig. 38.

Summary

Very little sexual dimorphism in root angulation is present in any of the pongids or in H.sapiens, and its occurrence is mainly limited to the first and second molars. Only Pan is sexually dimorphic for root divergence, and for M_1^- only.

Pongids

In Gorilla, there is very little sexual dimorphism in root angulation; the male and female mean values are significantly different for only a few roots ($P < 0.01$ M_2^-m P^4mb; $P < 0.05$ M^1mb M^1db M^2l). The distal angulation of the M_2^- mesial and M^2 lingual roots is slightly greater in females than males, while that of the P^4 mesiobuccal root and M^1 buccal roots is slightly greater in males. However, the

Fig. 36 : Male and female mean values for mandibular root angulation in the pongids and Homo sapiens

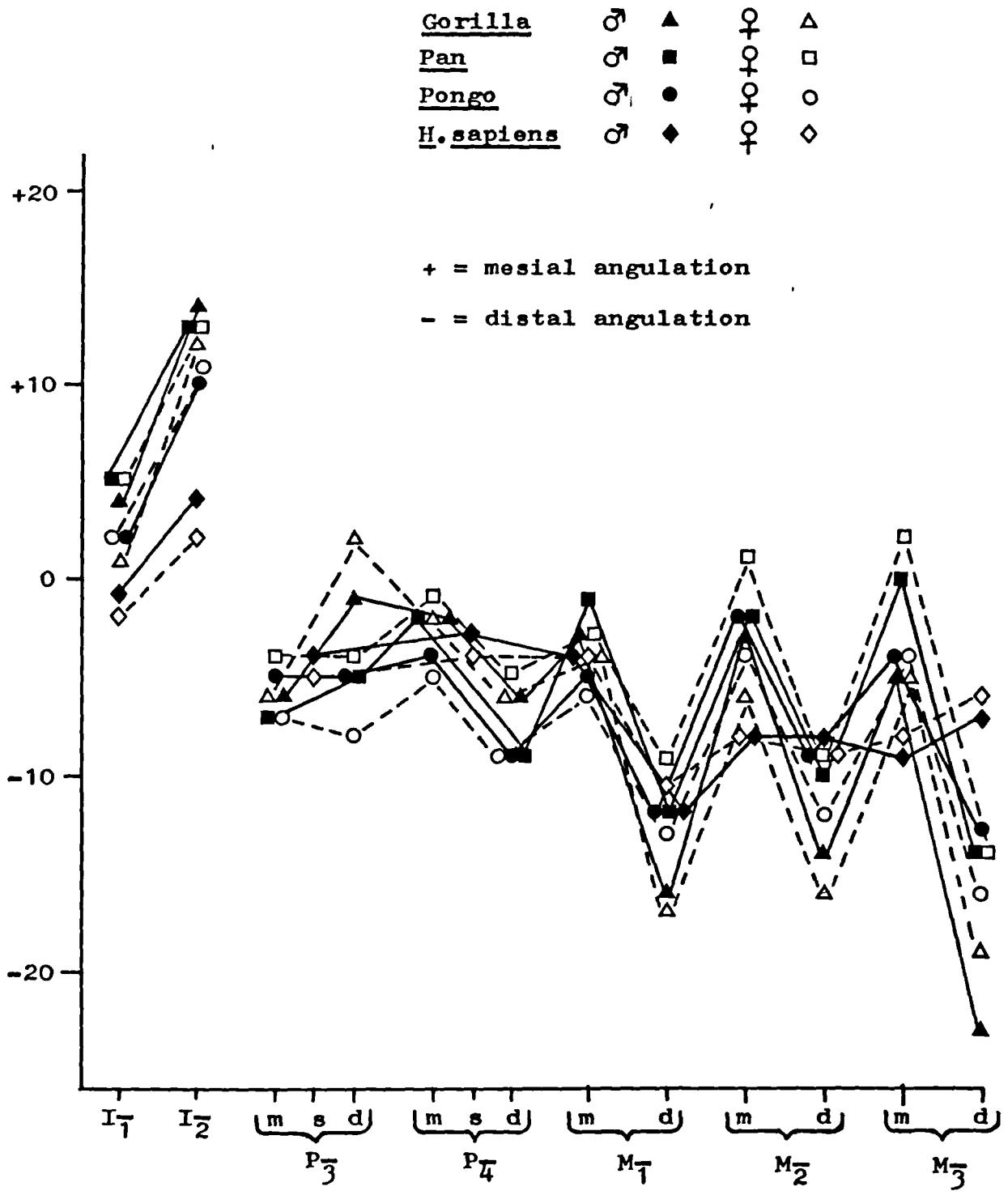


Fig. 37 : Male and female mean values of maxillary root angulation in the pongids and Homo sapiens

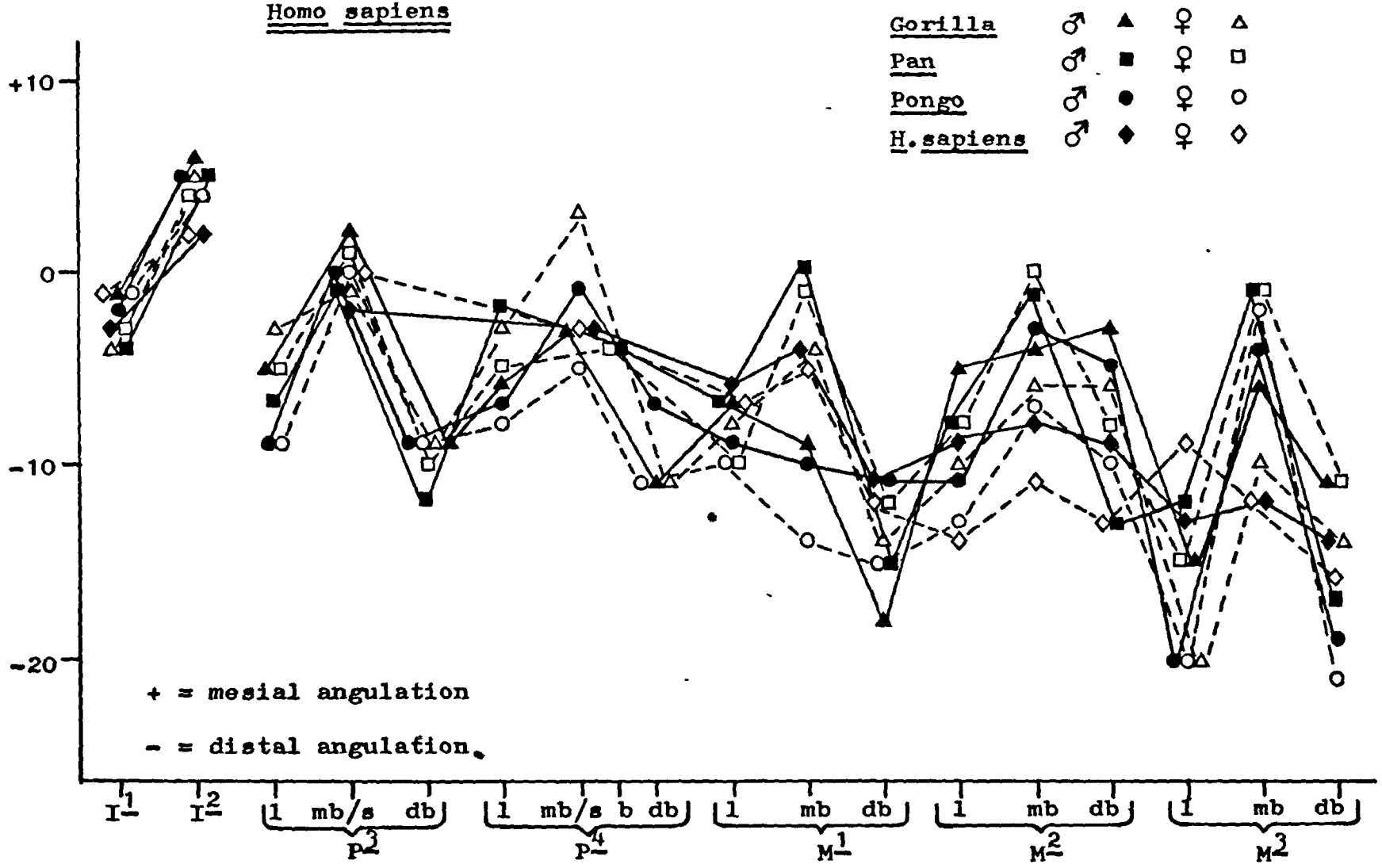
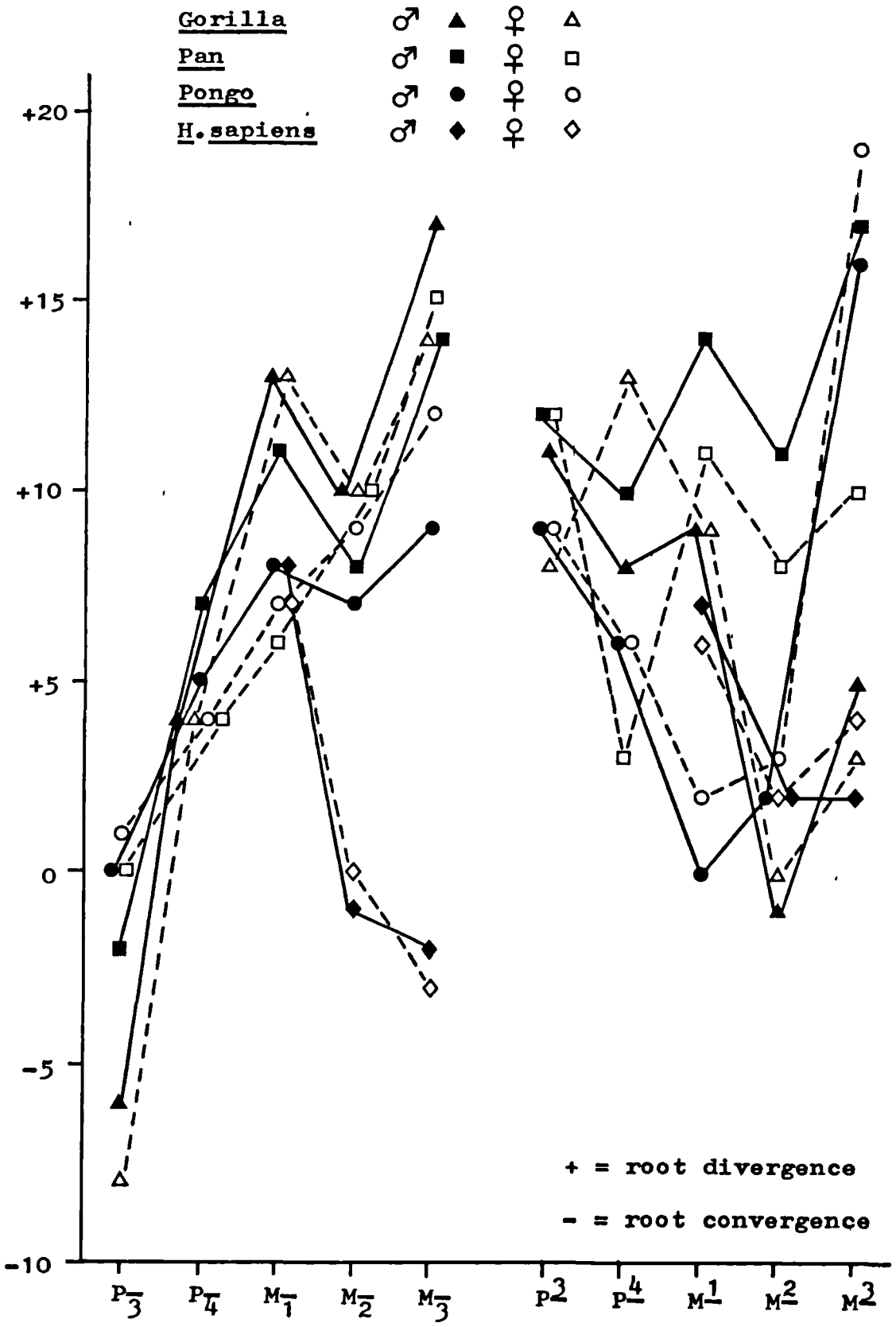


Fig. 38 : Male and female mean values of root divergence in the pongids and Homo sapiens



male ranges completely overlap the female ranges for the mesiobuccal roots of $P^{\underline{4}}$ and $M^{\underline{1}}$ (F-ratio:$P < 0.05$ $M^{\underline{1}}$mb). No sexual dimorphism in root divergence is present in Gorilla.

The distal angulation of the $P_{\overline{4}}$ and $M_{\overline{1}}$ distal roots is slightly greater in Pan males than females ($P < 0.01$ $P_{\overline{4}}$; $P < 0.05$ $M_{\overline{1}}$). For the $M_{\overline{1}}$ distal root, the male range is more extensive than, and completely overlaps, the female range. Also, the divergence of the $M_{\overline{1}}$ roots is greater in Pan males than females; though males may show very marked divergence between the roots, the male range completely overlaps the female.

In Pongo, sexual dimorphism in root angulation is present only in some second molar roots ($P < 0.05$ $M_{\overline{2}}$d $M^{\underline{2}}$db). The distal angulation of the $M_{\overline{2}}$ distal and $M^{\underline{2}}$ distobuccal roots is slightly greater in the females than in the males. No sexual dimorphism in root divergence is present in Pongo.

Homo sapiens

The distal angulation of the $M^{\underline{2}}$ distobuccal root is also slightly greater in H.sapiens females than males ($P < 0.05$). This is the only root in the pooled H.sapiens sample which is sexually dimorphic for root angulation, and none of the molars is sexually dimorphic for root divergence.

When the H.sapiens subsamples are assessed separately, the Romano-British are also sexually dimorphic for the $M^{\underline{2}}$ distobuccal root ($P < 0.01$) which shows greater distal

angulation in the females. In addition, they are sexually dimorphic for the I_2^- root ($P < 0.05$). This root tends to be vertically orientated in the females, but is angled mesially in the males; however, while males may show marked mesial angulation for this root, the distal part of the male range does completely overlap the female. In the Australian Aborigines, the males show slightly greater distal angulation for the M_1^- distal root, while the females show greater distal angulation for the M^{2-} mesiobuccal root ($P < 0.05$ M_1^-d M^{2-}mb).

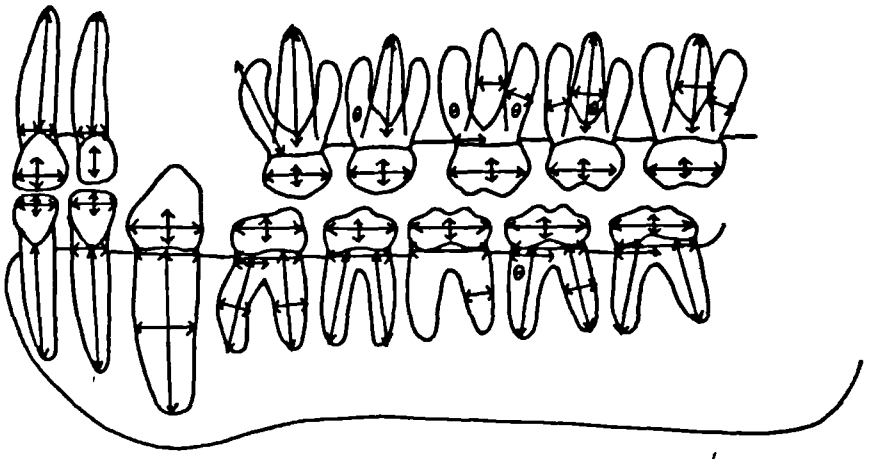
vii) Summary

Gorilla gorilla (Fig.39)

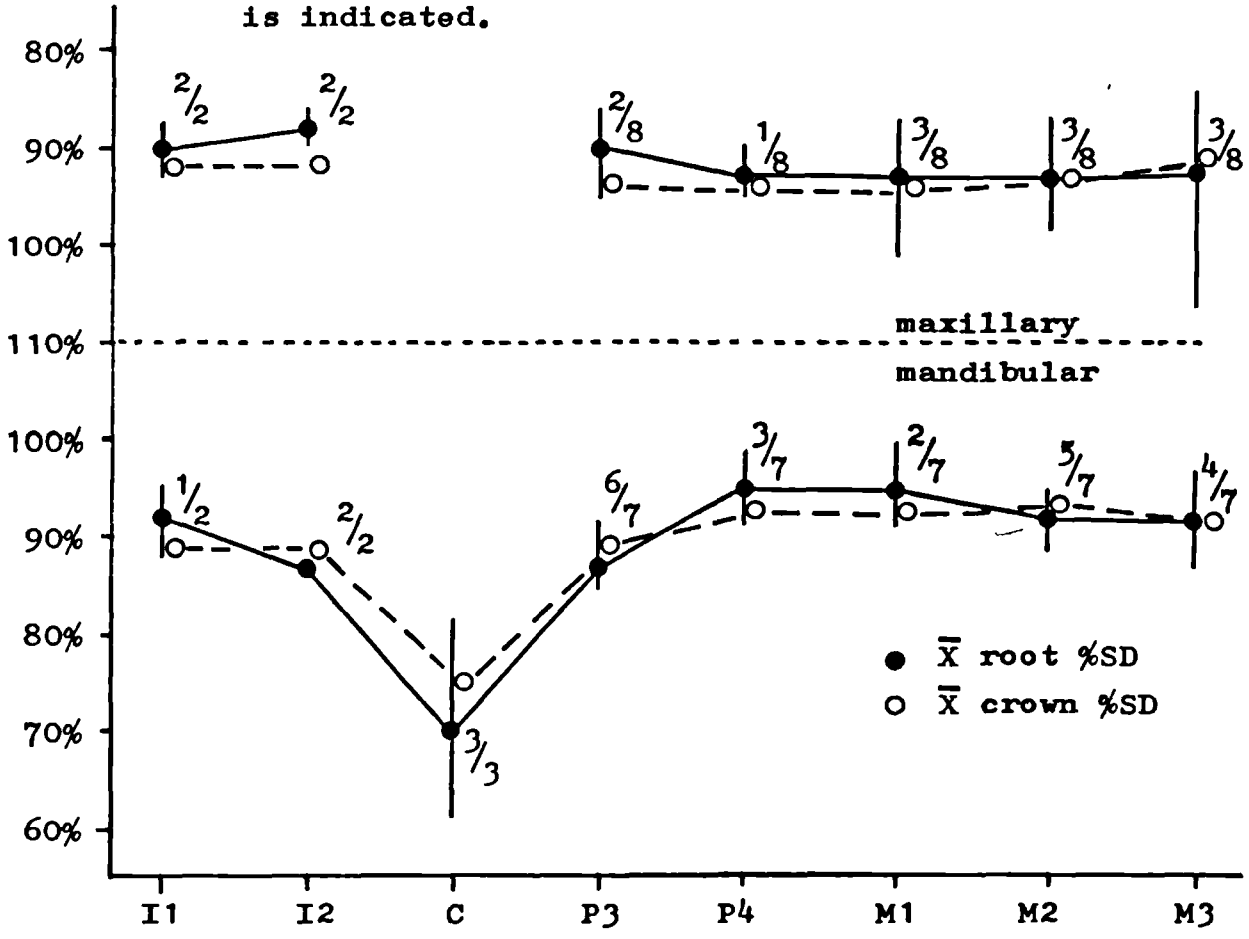
Of the measured Gorilla roots (C^{1-} not measured), the most pronounced sexual dimorphism is found in the C_1^-. Not only is this root much larger in males than females, particularly in its mesiodistal diameters for which the male and female ranges are discontinuous, but it is also more robust (%SD:root MD=62%, neck MD=67%, root ht=82%, root robust.=76%). The presence of such pronounced sexual dimorphism in the C_1^- root explains the very high variability of the dimensions in the pooled-sex sample ($\bar{X}$ C.V.: ♂+♀ =20.4, ♂=11.2, ♀=9.4). In Gorilla, sexual dimorphism tends to decrease in degree and extent with increasing distance - both mesially and distally - from the canine region, particularly in the mandibular teeth. All incisors are sexually dimorphic for root height and, with one exception, for neck mesiodistal diameter, but the degree of dimorphism is greater in the laterals than in the centrals. The degree of sexual dimorphism in the incisor root dimensions is greater than found in the cheek-teeth - with the exception

Fig. 39 : Sexual dimorphism in the root and crown dimensions of Gorilla gorilla

a) ♂ & ♀ $\bar{X}$ values : $P \leq 0.05$



b) the $\bar{X}$ and range of %SD for the root dimensions of each tooth compared with the $\bar{X}$ %SD of the crown dimensions. The number of root dimensions for which ♂& ♀ $\bar{X}$ values are significantly different ($P \leq 0.05$) is indicated.



of P3. All P_3 root dimensions are sexually dimorphic with the exception of height of bifurcation - a dimension which is not sexually dimorphic in any Gorilla tooth - and the values of percentage sexual dimorphism for the sexually dimorphic dimensions are similar and range from 85% to 89%. In comparison, sexual dimorphism is much less extensive, though not less marked, in P^3, being present only in the root heights of the mesiobuccal and lingual roots (% SD:P^3mb=86%, P^3l=90%). Proceeding posteriorly through the mandibular cheek-teeth, sexual dimorphism tends to decrease in degree and extent from P_3 to M_1, and then to increase, more noticeably in extent, from M_1 to M_3. Thus, the expression of sexual dimorphism tends to be localised to the mesial and distal ends of the cheek-tooth row. The root dimensions generally reflect this pattern, though to varying degrees. Sexual dimorphism is present in all the cheek-teeth for neck mesiodistal diameter, being most marked in P_3 and least marked in P_4. Sexual dimorphism in root height is most marked in P_3 and M_3, and absent in M_1. Location of bifurcation is sexually dimorphic for P_3, M_2 and M_3, but not for P_4 and M_1. Root mesiodistal diameter follows the pattern mesially - both P_3 roots are sexually dimorphic for this dimension while the P_4 mesial to M_1 mesial roots are not - but distally, M_3 is not sexually dimorphic for this dimension, while the distal roots of M_1 and M_2 are. However, sexual dimorphism is more marked in the M_2 distal root than in the M_1 distal root. In comparison to the mandibular cheek-teeth, sexual dimorphism is less evident in the maxillary cheek-tooth roots. With the exception of the P^3 mesiobuccal root, none of the maxillary buccal roots are sexually dimorphic for root

height and, with the exception of a few molar buccal roots, none are for root mesiodistal diameter. The lack of sexual dimorphism in these roots does not necessarily result from similarity in male and female mean values; the value of percentage sexual dimorphism is less than 95% for many of the buccal roots, but the generally high variability of these dimensions in the males and females contributes to the lack of statistical significance between the male and female mean values. Sexual dimorphism is more evident in the lingual roots than in the buccal roots: all lingual root heights except that of $M^{\underline{1}}$ are sexually dimorphic, as are all molar lingual root mesiodistal diameters. The pattern seen in the mandibular cheek-teeth - of greater sexual dimorphism at the mesial and distal ends of the cheek-tooth row - is not obviously present in the maxillary cheek-teeth.

Generally, and with the notable exception of the $C_{\underline{1}}$ root dimensions, the presence of sexual dimorphism does not account for the high variability of some root dimensions in the pooled-sex Gorilla sample. Particularly, the dimensions for which high variability was recorded in the pooled-sex sample - the root heights and root mesiodistal diameters of the maxillary buccal roots and generally for root robusticity, height of bifurcation and height of bifurcation index - are mostly not sexually dimorphic in Gorilla, and high variability is also generally found in each of the sexes.

With the exception of the crown mesiodistal diameter of $I^{\underline{2}}$, both crown dimensions of each Gorilla tooth ($C^{\underline{1}}$

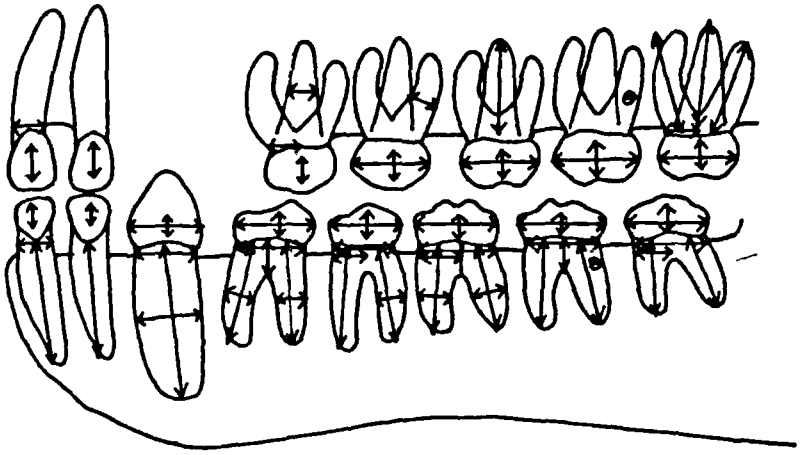
not measured) are sexually dimorphic to some degree, and the degree is usually similar to the average recorded for the root dimensions of the corresponding tooth. The most pronounced sexual dimorphism is exhibited by the $C_{\bar{1}}$ crown dimensions (%SD:crown MD=78%, crown BL=71%), being not as marked as the degree exhibited by neck mesiodistal diameter (67%) and root mesiodistal diameter (62%), but similar to that exhibited by root robusticity (76%) and root height (82%). The male and female ranges are discontinuous for crown buccolingual diameter and overlap slightly for crown mesiodistal diameter, and this marked sexual difference underlies the high variability of the dimensions in the pooled-sex sample (C.V.:crown MD ♂+♀ =16.0, ♂=10.1, ♀=10.0; crown BL ♂+♀ =19.6, ♂=11.2, ♀ =6.3).

Pongo pygmaeus (Fig.40)

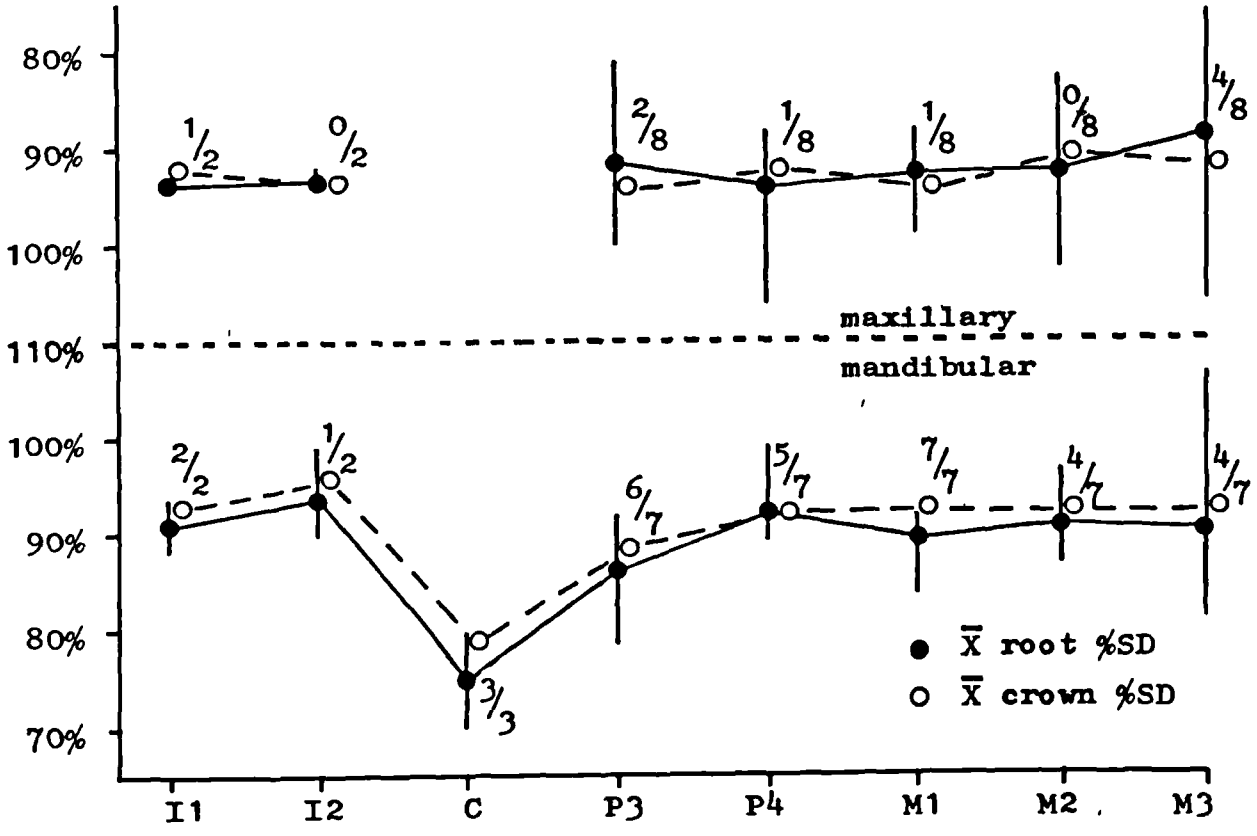
All the $C_{\bar{1}}$ root dimensions are sexually dimorphic to a pronounced degree in Pongo (%SD:root MD=70%, root ht.=75%, neck MD=79%). The male and female ranges do not overlap for root mesiodistal diameter and root height, though they do for neck mesiodistal diameter. These marked differences between the sexes underlie the high variability of the dimensions in the pooled-sex sample ($\bar{X}$ C.V.: ♂·♀ =18.6, ♂=8.7, ♀=12.8), though the females are themselves highly variable for root height and neck mesiodistal diameter. The degree and extent of sexual dimorphism declines from the $C_{\bar{1}}$ through the mandibular premolars. With the exception of location of bifurcation, all $P_{\bar{3}}$ root dimensions are sexually dimorphic, the values of percentage sexual dimorphism ranging from

Fig. 40 : Sexual dimorphism in the root and crown dimensions of Pongo pygmaeus

a) ♂ & ♀ $\bar{X}$ values : $P \leqslant 0.05$



b) the $\bar{X}$ and range of %SD for the root dimensions of each tooth compared with the $\bar{X}$ %SD of the crown dimensions. The number of root dimensions for which ♂ & ♀ $\bar{X}$ values are significantly different ($P \leqslant 0.05$) is indicated.



78% to 88%. For $P_{\bar{4}}$, all root dimensions except the mesiodistal diameter of the mesial root and height of bifurcation are sexually dimorphic, but generally to not the same degree as in $P_{\bar{3}}$, the values of percentage sexual dimorphism ranging from 89% to 91%. Sexual dimorphism is more extensive in the root dimensions of $M_{\bar{1}}$ than in the other molars. All Pongo $M_{\bar{1}}$ root dimensions are sexually dimorphic (%SD=84%-92%), while only neck mesiodistal diameter and the mesial and distal root heights are in $M_{\bar{2}}$ and $M_{\bar{3}}$, in addition to the $M_{\bar{2}}$ height of bifurcation and the $M_{\bar{3}}$ location of bifurcation. However, as far as root height is concerned, the degree of dimorphism increases from $M_{\bar{1}}$ to $M_{\bar{3}}$. Both mandibular incisors are sexually dimorphic to much the same degree for root height (%SD:$I_{\bar{1}}$=88%, $I_{\bar{2}}$=90%), but only $I_{\bar{1}}$ is for neck mesiodistal diameter and slightly so (%SD=93%).

In comparison to the mandibular roots, sexual dimorphism is much less evident in the maxillary root dimensions. Even root height, which is sexually dimorphic to some degree for every mandibular root, is sexually dimorphic for only a few maxillary roots - slightly so for the $M^{\bar{1}}$ lingual root (%SD=91%) but quite markedly so for the $M^{\bar{3}}$ roots (%SD:$M^{\bar{3}}$l=82%, $M^{\bar{3}}$mb=79%, $M^{\bar{3}}$db=83%). There is little evidence of a pattern in the sexual dimorphism displayed by the Pongo maxillary roots. In addition to the root heights just mentioned, the $I^{\bar{1}}$ neck mesiodistal diameter is slightly sexually dimorphic (%SD=94%), while more marked sexual dimorphism is found in the $P^{\bar{3}}$ location of bifurcation (%SD=82%) and lingual root mesiodistal diameter (%SD=87%), the $P^{\bar{4}}$ distal root mesiodistal diameter (%SD=89%), and the $M^{\bar{3}}$ location of bifurcation

(%SD=83%).

In the pooled-sex Pongo sample, root robusticity, height of bifurcation and height of bifurcation index were noted to be generally highly variable, as were the maxillary locations of bifurcation, many root heights and several mandibular root mesiodistal diameters. Generally, this high variability does not stem from sexual dimorphism, and most of these dimensions and indices are also highly variable in the separate sexes. On the other hand, sexual dimorphism does underlie the high variability recorded for the $C_{\bar{1}}$ root dimensions. A sexual difference of a different kind is that the Pongo females are highly variable, appearing more variable than the males, for many mandibular and maxillary premolar root heights, as they are also for $C_{\bar{1}}$ root height and neck mesiodistal diameter.

All measured crown buccolingual diameters are sexually dimorphic in Pongo, generally to a slight degree (%SD=90-93%) with the exceptions of the more marked dimorphism found in $P_{\bar{3}}$ crown buccolingual diameter (%SD=86%) and, particularly, in $C_{\bar{1}}$ crown buccolingual diameter (%SD=80%). In contrast, none of the incisor crown mesiodistal diameters are sexually dimorphic, nor is the P^3 dimension. Crown mesiodistal diameter is sexually dimorphic in the remaining cheek-teeth, to a slightly greater degree in $P_{\bar{3}}$ (%SD=89%) than in the others (%SD=91-94%). $C_{\bar{1}}$ crown mesiodistal diameter is markedly sexually dimorphic (%SD=78%). Thus, the pattern of sexual dimorphism exhibited by the crown dimensions

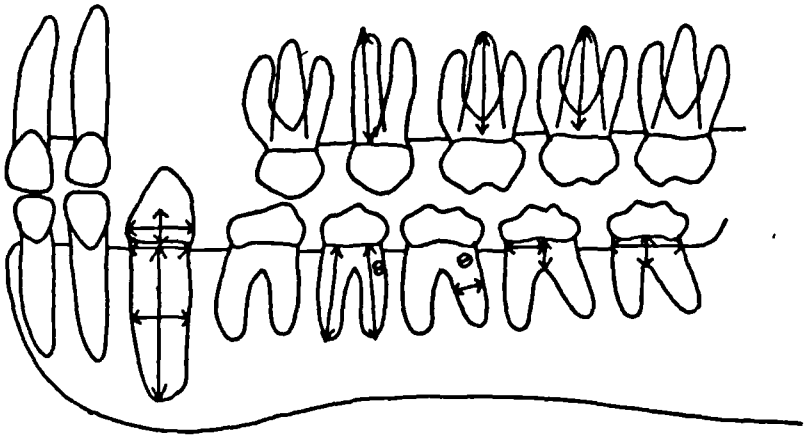
differs from that exhibited by the root dimensions in that sexual dimorphism is very nearly as extensive in the maxillary teeth ($C^{\underline{1}}$ not measured) as in the mandibular teeth. Generally, the degree of sexual dimorphism exhibited by the crown dimensions is similar to the average recorded for the root dimensions.

Pan troglodytes (Fig.41)

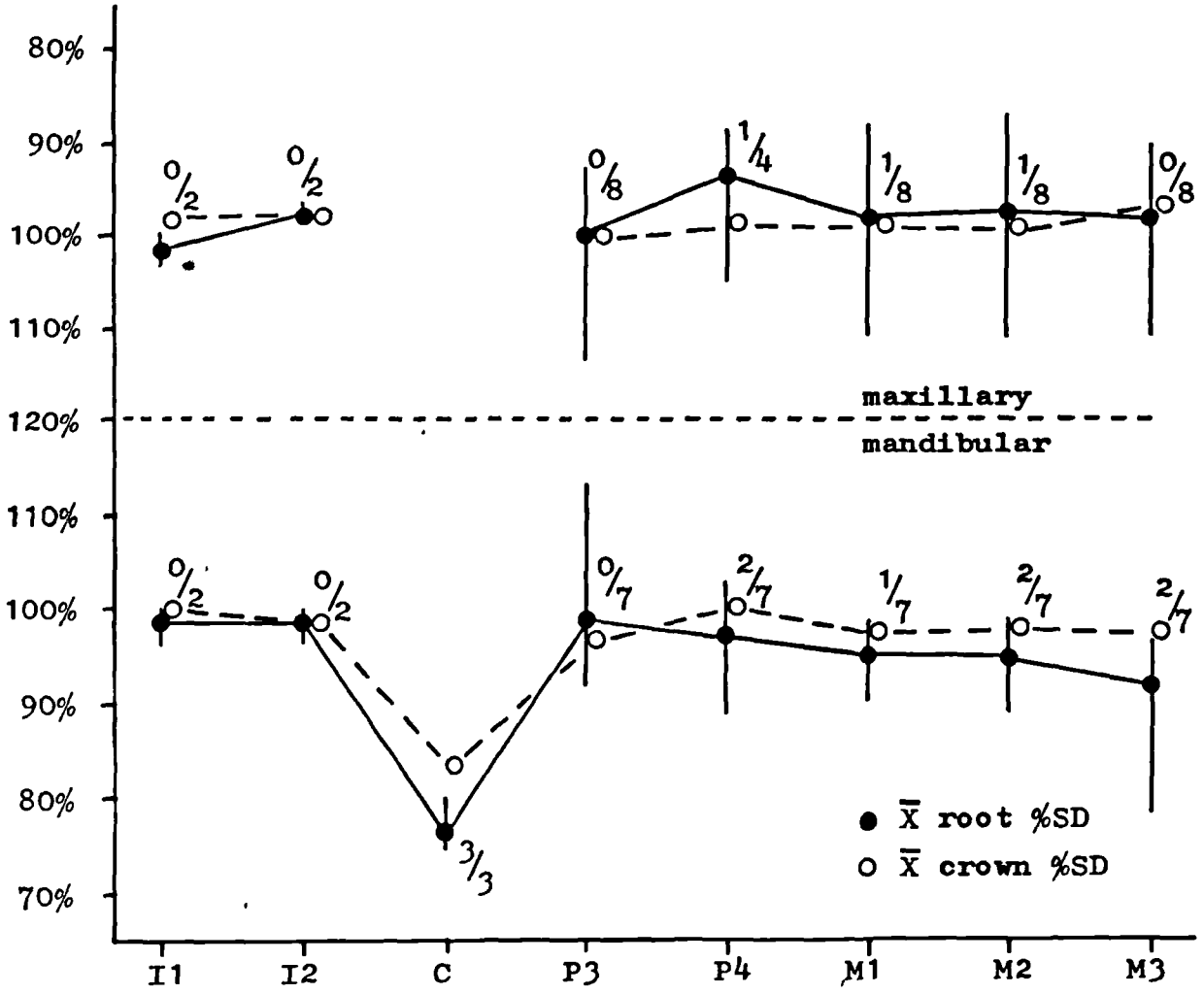
Overall, there is very little sexual dimorphism in the root dimensions of Pan. The $C_{\underline{1}}$ root dimensions are sexually dimorphic to a pronounced and similar degree (%SD:root MD=75%, root ht.=76%, neck MD=78%) and this underlies the high variability recorded in the pooled-sex sample for the root dimensions ($\bar{X}$ C.V.: ♂+♀ =16.7, ♂=9.7, ♀ =12.5). Otherwise, in the mandibular teeth sexual dimorphism is present only in the $P_{\underline{4}}$ root heights (%SD: $P_{\underline{4}}$m=89%, $P_{\underline{4}}$d=90%), the $M_{\underline{1}}$ distal root mesiodistal diameter (%SD=90%), the $M_{\underline{2}}$ height (%SD=89%) and location of bifurcation (%SD=93%), and the $M_{\underline{3}}$ neck mesiodistal diameter (%SD=94%) and height of bifurcation (%SD=78%). The $M_{\underline{3}}$ bifurcation is also relatively higher in males (%SD=78%), while in Pan females, the $P_{\underline{4}}$ mesial root is slightly more robust (%SD=113%) than in the males. Root height is the only root dimension which exhibits sexual dimorphism in the maxillary teeth, and for the lingual roots of $2RP^{\underline{4}}$, $M^{\underline{1}}$ and $M^{\underline{2}}$ only (%SD:$2RP^{\underline{4}}$=89%, $M^{\underline{1}}$=88%, $M^{\underline{2}}$=89%). In addition, some maxillary buccal roots (%SD:$P^{\underline{3}}$mb=123%, $M^{\underline{2}}$mb=117%, $M^{\underline{2}}$db=117%) are most robust and the $P^{\underline{3}}$ bifurcation (%SD=125%) is relatively higher in Pan females than in males.

Fig. 41 : Sexual dimorphism in the root and crown dimensions of Pan troglodytes

a) ♂ & ♀ $\bar{X}$ values : $P \leqslant 0.05$



b) the $\bar{X}$ and range of %SD for the root dimensions of each tooth compared with the $\bar{X}$ %SD of the crown dimensions. The number of root dimensions for which ♂ & ♀ $\bar{X}$ values are significantly different ($P \leqslant 0.05$) is indicated.



With the notable exception of the $C_{\bar{1}}$ root dimensions, sexual dimorphism does not generally underlie the high variability recorded on many occasions for root dimensions in the Pan pooled-sex sample.

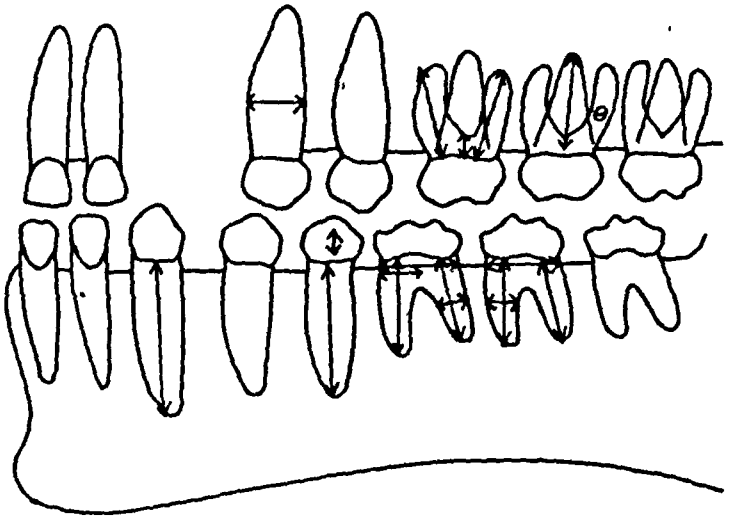
Of all the measured crown dimensions, only the crown buccolingual and mesiodistal diameters of the $C_{\bar{1}}$ are sexually dimorphic in Pan (%SD:crown MD=87%, crown BL=80%).

Homo sapiens (Fig.42)

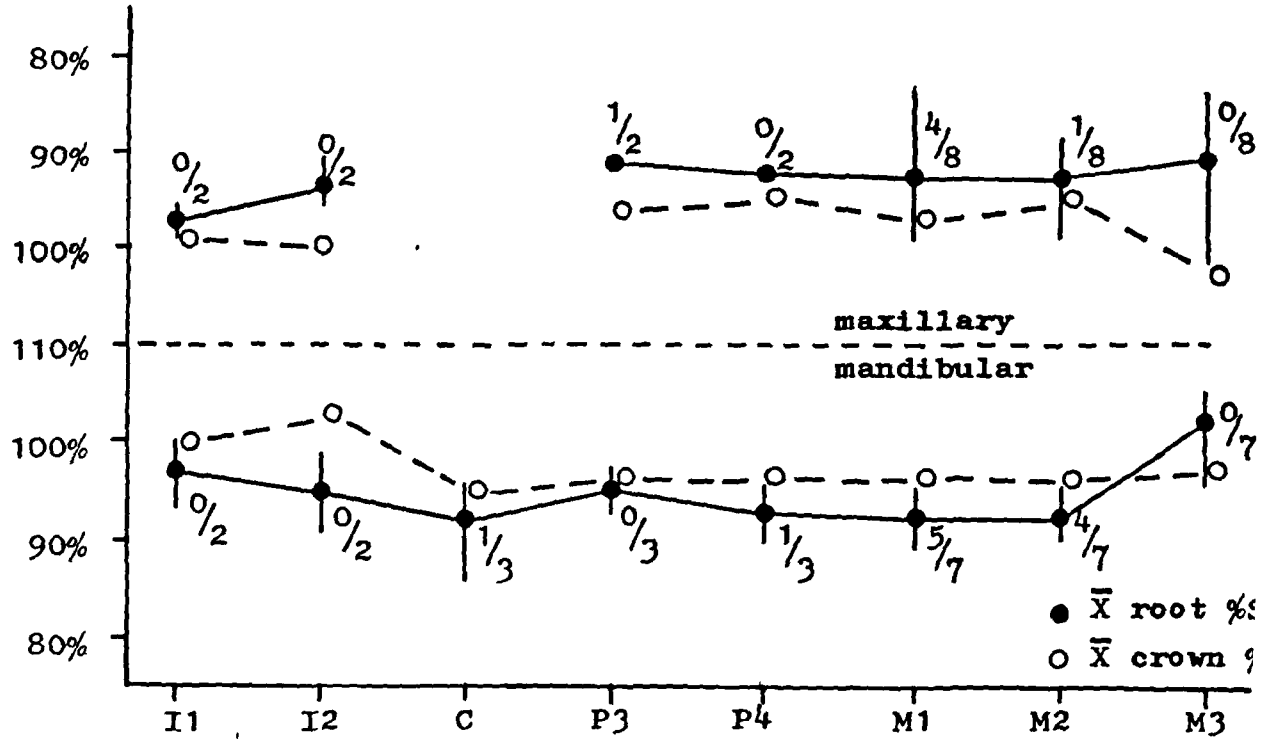
Sexual dimorphism in the root dimensions of H.sapiens is found most extensively in the molars, almost exclusively in $M_{\bar{1}}$, $M_{\bar{2}}$ and $M^{\underline{1}}$. In both $M_{\bar{1}}$ and $M_{\bar{2}}$, neck mesiodistal diameter is sexually dimorphic (%SD:$M_{\bar{1}}$=93%, $M_{\bar{2}}$=92%), as are the root heights of the mesial and distal roots (%SD:$M_{\bar{1}}$m=91%, $M_{\bar{1}}$d=93%, $M_{\bar{2}}$m=90%, $M_{\bar{2}}$d=90%). In addition, sexual dimorphism is present in the $M_{\bar{1}}$ location of bifurcation (%SD=92%), and in the root mesiodistal diameters of the $M_{\bar{1}}$ distal and $M_{\bar{2}}$ mesial roots (%SD:$M_{\bar{1}}$d=89%, $M_{\bar{2}}$m=91%). In common with $M_{\bar{1}}$ and $M_{\bar{2}}$, root height is sexually dimorphic in $M^{\underline{1}}$ - for the buccal root heights (%SD:$M^{\underline{1}}$mb=90%, $M^{\underline{1}}$db=90%). Other $M^{\underline{1}}$ root dimensions which are sexually dimorphic are the root mesiodistal diameters of the distobuccal root (%SD=90%) and the height of bifurcation (%SD=84%). The only other molar root dimension which is sexually dimorphic is $M^{\underline{2}}$ lingual root height (%SD=88%), which contributes to this root being slightly more robust in females (%SD=112%) than in males. Apart from the molars already mentioned, there is little evidence of sexual dimorphism in the root dimensions of the remaining H.sapiens teeth. In the

Fig. 42 : Sexual dimorphism in the root and crown dimensions of Homo sapiens

a) ♂ & ♀ $\bar{X}$ values : $P \leqslant 0.05$



b) the $\bar{X}$ and range of %SD for the root dimensions of each tooth compared with the $\bar{X}$ %SD of the crown dimensions. The number of root dimensions for which ♂ & ♀ $\bar{X}$ values are significantly different ($P \leqslant 0.05$) is indicated.



$C_{\overline{1}}$ and $P_{\overline{4}}$, root height is sexually dimorphic (%SD:$C_{\overline{1}}$=86%, $P_{\overline{4}}$=90%), and in $P^{\overline{3}}$, root mesiodistal diameter is sexually dimorphic (%SD=90%). Thus, in the roots of H.sapiens, sexual dimorphism finds most expression in the first and second molars, and of the dimensions, is most frequently expressed in root height. It is also apparent that sexual dimorphism makes little contribution to the high variability recorded for dimensions in the pooled-sex sample.

In comparison to the root dimensions, sexual dimorphism is present much less frequently in the crown dimensions of Homo sapiens. In this study, only the $P_{\overline{4}}$ crown buccolingual diameter appears to be sexually dimorphic (%SD=94%).

When the Romano-British and Australian Aborigines are assessed separately, the picture of sexual dimorphism differs in each of them. In the Romano-British, sexual dimorphism seems more in evidence in crown dimensions than in root dimensions, but there does seem to be an emphasis on the first and second molars. In addition to evidence of slight sexual dimorphism in first and second molar crown dimensions (%SD:crown MD $M_{\overline{1}}$=94%, $M_{\overline{2}}$=93%, $M^{\overline{2}}$=91%; crown BL $M_{\overline{1}}$=95%, $M_{\overline{2}}$=94%, $M^{\overline{2}}$=92%), both crown dimensions of the $C_{\overline{1}}$ (%SD:crown MD=93%, crown BL=91%) and the $I^{\overline{1}}$ crown buccolingual diameter (%SD=94%) are slightly sexually dimorphic. Some root dimensions of the first and second molars are sexually dimorphic (%SD:$M_{\overline{1}}$ neck MD=94%, $M_{\overline{1}}$ loc.bifurc.=88%, $M^{\overline{1}}$mb root ht.=89%, $M^{\overline{2}}$mb root MD=84%), in addition to the $I^{\overline{2}}$ neck

mesiodistal diameter (%SD=92%), but there seems to be no pattern underlying their occurrence. In the Audstralian Aborigine, there is more frequent expression of sexual dimorphism in root dimensions than in crown dimensions, but again there does seem to be an emphasis on the first and second molars. In the first and second molars, many root dimensions are sexually dimorphic, particularly in $M_{\overline{1}}$ and $M_{\overline{2}}$, some to quite a marked degree (%SD:neck MD $M_{\overline{1}}$=92%, $M_{\overline{2}}$=86%; $M^{\overline{1}}$ loc.bifurc.=86%; root ht. $M_{\overline{1}}$m=88%, $M_{\overline{2}}$m=85%, $M_{\overline{2}}$d=85%, $M^{\overline{1}}$mb=88%, $M^{\overline{1}}$db=87%, $M^{\overline{2}}$l=80%; root MD $M_{\overline{1}}$m=90%, $M_{\overline{1}}$d=82%, $M_{\overline{2}}$m=84%; ht.bifurc. $M_{\overline{1}}$=87%, $M_{\overline{2}}$=83%). In teeth other than molars, of the root dimensions sexual dimorphism is found only in root height (%SD:$C_{\overline{1}}$=80%, $P_{\overline{4}}$=86%, $I^{\overline{2}}$=81%, $P^{\overline{3}}$=83%). In contrast, there is very little sexual dimorphism in crown dimensions in the Australian Aborigines, but it is present in first and second molars, in addition to $P_{\overline{4}}$ (%SD:crown MD $M^{\overline{1}}$=92%, $M^{\overline{2}}$=90%; crown BL $P_{\overline{4}}$=92%, $M_{\overline{1}}$=95%).

Part III

Chapter 8 : The relationship of root height to other root, crown and jaw dimensions in the pongids and Homo sapiens

i) actual root height; inter-root and inter-tooth

ii) actual root height/other root dimensions

iii) actual root height/crown dimensions

iv) actual root height/jaw dimensions

v) summary

Chapter 8 : The relationship of root height to other root, crown and jaw dimensions in the pongids and Homo sapiens

In the assessments that follow, a value for the correlation coefficient (r) of at least 0.6 was used as a guideline for the recognition of an association between two dimensions. Even so, such a value of r indicates a relationship between dimensions where variation in one explains just less than 40% of the variation in the other (r^2=0.36). The correlation coefficients between dimensions are listed in Appendix I, along with the results of testing the significance of r.

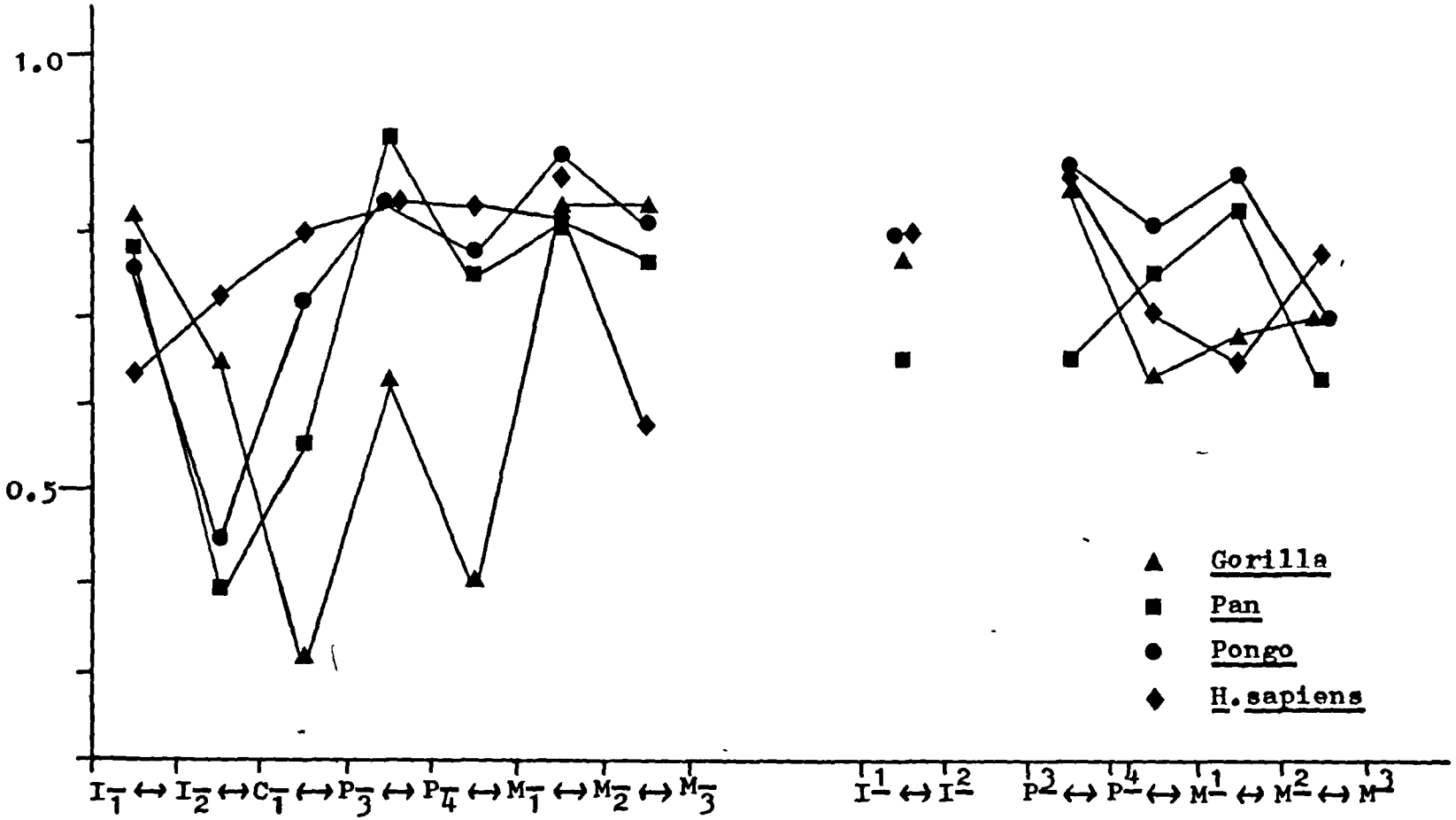
1) Actual root height; inter-root and inter-tooth

In the mandibular two-rooted teeth of pongids and Homo sapiens, mesial root height is highly correlated with distal root height with correlation coefficients ranging in value from 0.80 to 0.96. In contrast, usually only the mesiobuccal and distobuccal root heights are highly correlated in three-rooted maxillary teeth (the range of values of the correlation coefficient being 0.67 to 0.98) but there are exceptions. In Pongo, all P^4 root heights are highly correlated with each other (r:mb-db=0.93, mb-l=0.79, db-l=0.77) and in M^3, in addition to an association between the mesiobuccal and distobuccal roots, the heights of the mesiobuccal and lingual roots are also highly correlated. In contrast to the lack of high correlation between the root heights of either buccal root with the lingual root in the Pan

$3RP^{\underline{4}}$ (N.B. Pan $3RP^{\underline{4}}$ N=5), for the Pan $2RP^{\underline{4}}$ there is a strong correlation between the buccal and lingual root heights (r=0.76). In H.sapiens, all $M^{\underline{3}}$ root heights are highly correlated with each other (r:mb-db=0.97, mb-l=0.78, db-l=0.83). Apart from these observations, the correlation coefficients for root height between the mesiobuccal and lingual roots range in value from 0.25 to 0.69 and between the distobuccal and lingual roots range from 0.32 to 0.68.

Generally, within each jaw there is a strong relationship between the root height of a tooth and that of its neighbours (Fig.43) (In the following assessment of root height between teeth, the average of the separate root heights was used to represent root height in multi-rooted teeth). Where this does not apply, it is usually between teeth of different type, e.g. $I_{\underline{2}}$-$C_{\underline{1}}$, $P_{\underline{4}}$-$M_{\underline{1}}$, though in H.sapiens $M_{\underline{2}}$ root height is not highly correlated with $M_{\underline{3}}$ root height (r=0.58). The pongids differ in the pattern of correlation which surrounds the $C_{\underline{1}}$. In Gorilla, $C_{\underline{1}}$ root height is not well correlated to $P_{\underline{3}}$ root height (r=0.32), but it is correlated to the height of the $I_{\underline{2}}$ root (r=0.65). The opposite pattern is found in Pongo; $C_{\underline{1}}$ root height is correlated to $P_{\underline{3}}$ root height (r=0.72), but not to $I_{\underline{2}}$ root height (r=0.45). In Pan, neither $I_{\underline{2}}$ root height (r=0.39) nor $P_{\underline{3}}$ root height (r=0.56) shows any definite relationship with $C_{\underline{1}}$ root height. H.sapiens differs from the pongids in that $C_{\underline{1}}$ root height is correlated to both $I_{\underline{2}}$ root height (r=0.73) and $P_{\underline{3}}$ root height

Fig 43 : Correlation coefficients for actual root height between adjacent teeth in the pongids and Homo sapiens (average root height used for multi-rooted teeth)



(r=0.80). In the Gorilla mandibular dentition, unlike the other samples, $P_{\overline{4}}$ root height is poorly correlated with $M_{\overline{1}}$ root height (r=0.40). In the maxillary dentition of each sample ($C^{\underline{1}}$ not measured), the incisor root heights are highly correlated, and in the postcanine dentition so is the root height of each tooth with its neighbours.

In the mandibular dentition, the overall pattern of correlation for root height differs noticeably between H.sapiens and the pongids (Fig.43). In H.sapiens, the intensity of relationship increases smoothly from the $I_{\overline{1}}$-$I_{\overline{2}}$ correlation (r=0.64) to the $P_{\overline{4}}$-$M_{\overline{1}}$ correlation (r=0.83) and then decreases to the $M_{\overline{2}}$-$M_{\overline{3}}$ correlation (r=0.58). This is unlike the pattern found in the pongids in which the intensity of relationship fluctuates along the tooth row. In the maxillary dentition, the pattern of correlation does not differ noticeably between H.sapiens and the pongids, particularly Gorilla, but the correlations around the $C^{\underline{1}}$ were not assessed. Generally, the pattern of correlation for root height is similar in Pan and Pongo, differing from Gorilla in the region of the $C_{\overline{1}}$ and mandibular premolars, and of $P^{\underline{4}}$, $M^{\underline{1}}$ and $M^{\underline{2}}$.

ii) Actual root height/other root dimensions

The relationship of root height to other root dimensions was investigated in a preliminary way by correlating actual root height with root mesiodistal diameter for all postcanine roots plus the $C_{\overline{1}}$ root.

In addition, correlation coefficients were calculated between actual root height and neck mesiodistal diameter, location of bifurcation, projected root height, height of bifurcation and root angulation for mandibular roots.

With a few exceptions, root height and root mesiodistal diameter are poorly correlated in the pongid and H.sapiens dentitions. Notably, these two dimensions are highly correlated in the pongid C_1^- (r:Gorilla=0.65, Pan=0.74, Pongo=0.65), but not in the C_1^- of H.sapiens (r=0.26). Instead, in H.sapiens high correlation between these dimensions is found in the maxillary premolar roots (r:P^3=0.76, P^4=0.60) and also in the M_1^- distal root (r=0.62).

Overall, and with the exception of projected root height, there is very little evidence of any relationship between actual root height and the other root dimensions in the mandibular dentition. In the pongids, neck mesiodistal diameter and actual root height are highly correlated in the C_1^- (r:Gorilla=0.69, Pan=0.66, Pongo=0.69) and additionally in the M_2^- mesial root of Gorilla (r=0.61). In H.sapiens, strong correlation between these dimensions, and also between actual root height and location of bifurcation, is found only in molar roots (r:neck MD - M_1^-m=0.70, M_1^-d=0.64, M_2^-m=0.71, M_2^-d=0.71; loc.bifurc. - M_1^-d=0.64, M_2^-m=0.60, M_2^-d=0,61). Generally, there is no relationship between either height of bifurcation or root angulation and actual root height, though isolated occurrences of high correlation were

recorded in Pan (r:ht.bifurc. M_3^-m=0.67, root ang. P_4^-d= -0.69) and Pongo (r:ht.bifurc. P_3^-d=0.62). As would be expected when comparing two slightly different measures of the same structure, there is a very close relationship between projected root height and actual root height - the value of the correlation coefficient is not less than 0.92 in any of the samples.

iii) Actual root height/crown dimensions

The relationship of root height to crown size was investigated by calculating the correlation coefficients between actual root height and each of the following three measures of crown size: crown mesiodistal diameter, crown buccolingual diameter and crown area (crown MD X crown BL).

In each of the pongids, a strong correlation between root height and crown dimensions is present in the C_1^-. With the exception of the crown mesiodistal diameter in Pan, the three C_1^- crown dimensions are highly correlated with root height in each of the pongids and all to much the same degree (r:crown MD - Gorilla=0.65, Pongo=0.65; crown BL - Gorilla=0.65, Pan=0.70, Pongo=0.68; crown area - Gorilla=0.62, Pan=0.64, Pongo=0.71). Otherwise, root height is negatively correlated with crown mesiodistal diameter and crown area in the Pan I_2^- (r:crown MD=0.62, crown area=0.61), and positively correlated with the same dimensions in the M_2^- distobuccal root of Pongo (r:crown MD=0.65, crown area=0.64). Thus, with the exception of the C_1^-, there is generally no correlation

between root height and crown size in the pongids.

In comparison to the pongids, relationship between root height and crown dimensions is more extensive in H.sapiens. In the mandibular dentition, crown mesiodistal diameter and crown area are highly correlated with root height in $C_{\bar{1}}$, $P_{\bar{3}}$, $M_{\bar{1}}$ and $M_{\bar{2}}$ (r:crown MD - $C_{\bar{1}}$=0.72, $P_{\bar{3}}$=0.62, $M_{\bar{1}}$m-0.60, $M_{\bar{2}}$m=0.70, $M_{\bar{2}}$d=0.70; crown area - $C_{\bar{1}}$=0.68, $P_{\bar{3}}$=0.61, $M_{\bar{1}}$m=0.61, $M_{\bar{2}}$m=0.71, $M_{\bar{2}}$d=0.69), while crown buccolingual diameter and root height are highly correlated for the $C_{\bar{1}}$ and $M_{\bar{2}}$ roots (r:$C_{\bar{1}}$=0.63, $M_{\bar{2}}$m=0.72, $M_{\bar{2}}$d=0.66). All the crown dimensions are highly correlated with root height in the maxillary premolars and $M^{\bar{2}}$ buccal roots (r:crown MD - $P^{\bar{3}}$=0.69, $P^{\bar{4}}$=0.60, $M^{\bar{2}}$mb=0.72, $M^{\bar{2}}$db=0.73; crown BL - $P^{\bar{3}}$=0.63, $P^{\bar{4}}$=0.60, $M^{\bar{2}}$mb=0.66, $M^{\bar{2}}$db=0.63; crown area - $P^{\bar{3}}$=0.69, $P^{\bar{4}}$=0.60, $M^{\bar{2}}$mb=0.71, $M^{\bar{2}}$db=0.70). Additionally, root height is highly correlated with crown mesiodistal diameter and crown area in $I^{\bar{2}}$ (r:crown MD=0.68, crown area=0.69) and with crown mesiodistal diameter for the $M^{\bar{1}}$ mesiobuccal (r=0.61) and the $M^{\bar{3}}$ lingual roots (r=0.69).

iv) Actual root height/jaw dimensions

The samples differ in the extent to which root height is related to mandibular length. Gorilla and H.sapiens are similar in that the heights of the $I_{\bar{1}}$, $C_{\bar{1}}$ and $M_{\bar{2}}$ roots are correlated with mandibular length, and so too is $P_{\bar{3}}$ root height in H.sapiens (r:Gorilla - $I_{\bar{1}}$=0.61, $C_{\bar{1}}$=0.76, $M_{\bar{2}}$m=0.62; H.sapiens - $I_{\bar{1}}$=0.69, $C_{\bar{1}}$=0.78, $P_{\bar{3}}$=0.61, $M_{\bar{2}}$m=0.62, $M_{\bar{2}}$d=0.62). Such a relationship is much less evident in Pan, being found only in the

$C_{\bar{1}}$ (r=0.62), and in Pongo, being found only in $I_{\bar{1}}$ and the $C_{\bar{1}}$ ($r:I_{\bar{1}}=0.62$, $C_{\bar{1}}=0.80$). In the pongid maxillary dentition, there is less evidence of relationship between root height and palatal length than found in the corresponding dimensions of the mandibular dentition. Only incisor root height is related to palatal length in Gorilla ($r:I^{\underline{1}}=0.63$, $I^{\underline{2}}=0.62$), while in the other pongids no root heights are so related. In H.sapiens, high correlations are more numerous in the maxillary dentition than in the mandibular dentition; the root heights of all measured teeth except $M^{\underline{1}}$ are highly correlated with palatal length ($r:I^{\underline{1}}=0.61$, $I^{\underline{2}}=0.68$, $P^{\underline{3}}=0.80$, $P^{\underline{4}}=0.71$, $M^{\underline{2}}=0.69$, $M^{\underline{3}}=0.67$).

Relationship between root height and mandibular depth shows much the same pattern in the pongids as that described between mandibular length and root height. Only $C_{\bar{1}}$ root height is highly correlated with mandibular depth in Pan (r=0.70), and Pongo (r=0.71), while all anterior root heights plus $P_{\bar{4}}$ and $M_{\bar{2}}$ root heights are in Gorilla ($r:I_{\bar{1}}=0.64$, $I_{\bar{2}}=0.60$, $C_{\bar{1}}=0.71$, $P_{\bar{4}}m=0.62$, $P_{\bar{4}}d=0.63$, $M_{\bar{2}}d=0.63$). In H.sapiens, only the root heights of $I_{\bar{2}}$ and $P_{\bar{4}}$ are highly correlated with mandibular depth ($r:I_{\bar{2}}=0.61$, $P_{\bar{4}}=0.65$).

Generally, there is little evidence of relationship between root height and palatal breadth - only isolated examples of high correlations between these dimensions are recorded for Gorilla ($r:I^{\underline{1}}=0.60$), Pongo ($r:M^{\underline{3}}=0.65$) and H.sapiens ($r:P^{\underline{3}}=0.60$). None of the correlation coefficients between root height and palatal index are

sufficiently large in any of the samples to suggest significant inter-relationship between these two dimensions.

v) Summary

For the most part, root height bears little relationship to other tooth dimensions or to jaw dimensions in the pongids. However, at least one area of high correlation between root height and the other dimensions is found in the pongids. $C_{\bar{1}}$ root height is highly correlated not only with other $C_{\bar{1}}$ root dimensions - neck mesiodistal diameter and root mesiodistal diameter - but also with $C_{\bar{1}}$ crown dimensions, mandibular length and mandibular depth. The only exception to this is that $C_{\bar{1}}$ root height is not highly correlated with crown mesiodistal diameter in Pan (r=0.49). In samples of Gorilla and Pongo (Johnson, 1978), the canine region was also found to be an area of high correlation between crown dimensions and several measures of body size. In Gorilla, incisor root height is highly correlated with jaw dimensions (r:mandib.length/$I_{\bar{1}}$=0.61; mandib.depth/$I_{\bar{1}}$= 0.64,/$I_{\bar{2}}$=0.60; palatal length/$I^{\underline{1}}$=0.63,/$I^{\underline{2}}$=0.62; palatal breadth/$I^{\underline{1}}$=0.60), but this is not so in the other pongids though $I_{\bar{1}}$ root height is highly correlated with mandibular length in Pongo (r=0.62). Otherwise, in the pongids, isolated instances of high correlation occur between root height and the other dimensions, but there is no clear pattern to their occurrence.

The incidence of high correlation between root height and other dimensions in H.sapiens is greater than found in the pongids. In each jaw, there are two regions of high correlation. High correlation is present anteriorly - in the mandible in the region of the $C_{\overline{1}}$ and $P_{\overline{3}}$, and in the maxilla in the region of the premolars, and in both jaws high correlation is found posteriorly in the region of the second molar. In the $C_{\overline{1}}$ and $P_{\overline{3}}$, root height correlates with crown dimensions and mandibular length, but not with other root dimensions. Root height shows more extensive correlation in $M_{\overline{2}}$; for each root, high correlation exists between root height and other root dimensions - neck mesiodistal diameter and location of bifurcation, the crown dimensions and mandibular length. The region of high correlation extends mesially from $M_{\overline{2}}$ into $M_{\overline{1}}$. $M_{\overline{1}}$ distal root height is correlated with root mesiodistal diameter, neck mesiodistal diameter and location of bifurcation, while $M_{\overline{1}}$ mesial root height is highly correlated with neck mesiodistal diameter, crown mesiodistal diameter and crown area. In the maxillary dentition, the $M^{\overline{2}}$ buccal root heights are strongly correlated with the crown dimensions and palatal length, while the premolar root heights are with root mesiodistal diameter, the crown dimensions and the palatal dimensions. In addition, strong correlation extends mesially from the premolars into the incisors and distally from $M^{\overline{2}}$ into $M^{\overline{3}}$ - for $I^{\overline{1}}$, $I^{\overline{2}}$ and $M^{\overline{3}}$, root height shows definite relationship with crown mesiodistal diameter and palatal length (r:root ht./crown MD - $I^{\overline{2}}$=0.68, $M^{\overline{3}}$=0.69; root ht./palatal length - $I^{\overline{1}}$=0.61, $I^{\overline{2}}$=0.68, $M^{\overline{3}}$=0.67).

The correlation coefficients recorded in this study between root height and the crown dimensions for H.sapiens are much larger than those published by Garn et al (1978a,c) for the $C_{\bar{1}}$ to $M_{\bar{2}}$ - for these teeth no correlation coefficient was greater than 0.24, indicating an absence of relationship between root height and crown dimensions in contrast to the comment of these authors (Garn et al, 1978c). This discrepancy between studies in the values of the correlation coefficient for root height/crown dimension correlations may reflect, at least to some degree, the smaller sample size of the present study compared with the study of Garn et al (1978a,c). Garn et al (1977) have noted the effect of small sample size on the magnitude of the correlation coefficient. The high level of correlation between the root heights of some mandibular teeth and both mandibular length and mandibular depth in the H.sapiens sample of this study contrasts with the absence of relationship, as indicated by a study conducted by Garn et al (1980), between the root heights of the $C_{\bar{1}}$ to $M_{\bar{2}}$ and three measures of facial size.

In contrast to the frequent lack of relationship between root height and other tooth dimensions, in the pongids and H.sapiens a relationship usually exists between the root height of a tooth and that of its neighbours. These findings are in agreement with the results of previous studies on the human dentition (Garn et al, 1978b; Selmer-Olsen, 1949), though the correlation coefficients determined in this study appear larger than those documented by these authors

for the postcanine dentition. The observation (Selmer-Olsen, 1949) that root height is more intensely correlated within tooth groups, e.g. P^3-P^4, than between tooth groups, e.g. P^4-M^1, is not apparent in this study for the H.sapiens dentition, though it seems generally to apply for the pongid dentition. On the whole, the pongid inter-tooth root height correlations determined in this study are similar to the pongid inter-tooth crown area correlations recorded by Mahler (1973). However, the absence of relationship between C_1 root height and either I_2 root height or P_3 root height does not apply to crown area, except to some degree in Pan. For crown area, (Mahler, 1973), the C_1-P_3 correlations were higher than the P_3-P_4 correlations and this was suggested to reflect the functional relationship of P_3 to the anterior dentition. As far as root height is concerned, the opposite applies - the P_3-P_4 correlations are of greater magnitude than the C_1-P_3 correlations.

Relationship between the individual root heights of multi-rooted teeth appears to be restricted to the mesial-distal direction. While high correlation exists between the root heights of the mesial and distal roots of mandibular two-rooted teeth and between the mesiobuccal and distobuccal roots of three-rooted maxillary teeth, this is not generally apparent between either of the buccal roots and the lingual root in the latter teeth.

Part III

Chapter 9 : Premolar root form in the comparative samples and in the fossil hominid sample

i) The comparative samples

ii) The fossil hominid sample

iii) Summary

Chapter 9 : Premolar root form in the comparative samples and in the fossil hominid sample

1) The comparative samples

With the exception of Gorilla, all the comparative samples display some intra-specific variation in premolar root form (Tables 15 & 16).

In the pongids, the mandibular premolars are typically two-rooted. In the case of $P_{\overline{3}}$, the roots are mesiobuccal and distal, and this root form is found in all Gorilla specimens, nearly all Pongo specimens (97%) and most Pan specimens (71%). Where this root form does not occur in Pan and Pongo, the $P_{\overline{3}}$ has the radiographic appearance of being single-rooted, though in some instances the root is clearly marked by longitudinal root grooves. It is possible that such roots have two apices, but that their separate identities have been obscured radiographically through superimposition. In Pan, the percentage incidence of single-rooted $P_{\overline{3}}$ ($1RP_{\overline{3}}$) appears greater in females (46%) than in males (20%). The single Pongo specimen which has this root form is also female. In none of the pongid samples is there variation in $P_{\overline{4}}$ root number. The pongid $P_{\overline{4}}$ is two-rooted, the roots being mesial and distal.

The mandibular premolars of Homo sapiens are typically single-rooted. In this study, variation in root form was recorded for $P_{\overline{3}}$, but not for $P_{\overline{4}}$. In one

Table 15 : Percentage incidence of mandibular premolar root number variations in the comparative samples

	$P_{\overline{3}}$					$P_{\overline{4}}$				
	N	2R:M+D	2R:MB+D	2T	1R	N	2R:M+D	2R:MB+D	2T	1R
Gorilla ♂+♀	40	0%	100%	0%	0%	39	100%	0%	0%	0%
♂	23	0%	100%	0%	0%	22	100%	0%	0%	0%
♀	17	0%	100%	0%	0%	17	100%	0%	0%	0%
Pan ♂+♀	31	0%	71%	0%	29%	31	100%	0%	0%	0%
♂	20	0%	80%	0%	20%	20	100%	0%	0%	0%
♀	11	0%	55%	0%	46%	11	100%	0%	0%	0%
Pongo ♂+♀	34	0%	97%	0%	3%	34	100%	0%	0%	0%
♂	19	0%	100%	0%	0%	19	100%	0%	0%	0%
♀	15	0%	93%	0%	7%	15	100%	0%	0%	0%
H.sapiens ♂+♀	32	0%	0%	3%	97%	33	0%	0%	0%	100%
♂	15	0%	0%	7%	93%	15	0%	0%	0%	100%
♀	17	0%	0%	0%	100%	18	0%	0%	0%	100%

Table 16: Percentage incidence of maxillary premolar root number variations in the comparative samples

	P^3				P^4			
	N	3R	2R	1R	N	3R	2R	1R
Gorilla ♂+♀	40	100%	0%	0%	40	100%	0%	0%
♂	23	100%	0%	0%	23	100%	0%	0%
♀	17	100%	0%	0%	17	100%	0%	0%
Pan ♂+♀	30	90%	10%	0%	30	17%	83%	0%
♂	19	95%	5%	0%	20	15%	85%	0%
♀	11	82%	18%	0%	10	20%	80%	0%
Pongo ♂+♀	26	92%	8%	0%	30	93%	7%	0%
♂	14	100%	0%	0%	17	94%	6%	0%
♀	12	83%	17%	0%	13	92%	8%	0%
H.sapiens ♂+♀	30	0%	17%	83%	32	0%	0%	100%
♂	16	0%	25%	75%	16	0%	0%	100%
♀	14	0%	7%	93%	16	0%	0%	100%

male Australian Aborigine, the P_3 root was clearly divided for nearly half the root height.

Typically, P^3 is three-rooted in the pongids. The roots are mesiobuccal, distobuccal and lingual, as in maxillary molars, and this root form was recorded for all Gorilla specimens, and nearly all Pongo (92%) and Pan (90%) specimens. The remaining Pongo and Pan specimens have two-rooted P^3s in which the roots are buccal and lingual. This root form was present in two Pongo females, and in one Pan male and two Pan females. P^4 is not typically three-rooted in all the pongids; it is in Gorilla and Pongo, but not in Pan. As for P^3, P^4 is three-rooted in all Gorilla specimens. In Pongo, the incidence of the three-rooted form is much the same in P^4 (93%) as in P^3 (92%), and the two-rooted P^4 was recorded in one male and one female Pongo specimen. In contrast to the other pongids, P^4 is typically two-rooted in Pan. Only 17% of Pan specimens have three roots, the remainder being two-rooted. The incidence of the two-rooted form appears similar in males (85%) and females (80%) (contra the P_3).

Both maxillary premolars of Homo sapiens are typically single-rooted. However, while variation in root number was not documented for P^4, it was for P^3. In this H.sapiens sample, P^3 was single-rooted in 83% of specimens, and two-rooted in 17%. The incidence of the two-rooted form appears higher in males (25%) than in females (7%).

It had been hoped to examine the possibility of relationship between crown dimensions and root number

in the premolars of the comparative samples. However, with a couple of exceptions, this was not possible, either because there was no intra-specific variation in root number for a particular premolar or, if there was, because the incidence of the unusual form was insufficiently large to allow comparison with the usual form. Comparison of crown dimensions in premolars of differing root number could only be made for the P_3 and P^4 of Pan, and the P^3 of Homo sapiens. In none of these comparisons were the mean values of crown mesio-distal diameter or of crown buccolingual diameter significantly different between the usual and unusual root number.

ii) The fossil hominid sample

The variation of mandibular premolar root form encountered in the fossil hominid sample has been categorized into four basic groups:

A. P_3 2R:MB+D, P_4 2R:M+D

The P_3 is supported by two roots - mesiobuccal and distal. The mesiobuccal root is oval in cross-section, has a single root canal, is aligned obliquely with respect to the distal root, i.e. on a mesiobuccal-distolingual axis, and does not extend as far lingually as the distal root. The distal root is mesiodistally compressed and contains two pulp canals. The P_4 has two roots - mesial and distal - which are each similar to the P_3 distal root. The two roots are typically parallel to each other, mesiodistally compressed and orientated more-or-less transversely with respect to

the mesiodistal crown axis. In both premolars, the level of bifurcation between the roots is typically high, occurring within the cervical third of root height. Such a P_3 root form is clearly present in the fossil hominid specimens KNM-ER 403, KNM-ER 730 and L.H.4, and is possibly present in KNM-ER 725, KNM-ER 733, KNM-ER 1805 and KNM-ER 3729, while the P_4 root form is clearly present in KNM-ER 403, KNM-ER 725, MNM-ER 3729 and L.H.4 and possibly present in KNM-ER 730 and KNM-ER 733.

Mesiobuccal and distal roots for the P_3s of KNM-ER 403 and L.H.4 are indicated by the triangular, or trefoil shape, of the P_3 cross-section as seen on the specimen and by the presence of two roots, positioned mesially and distally, on the lateral radiograph. The diagnosis of mesiobuccal and distal roots for the P_3 of KNM-ER 730 rests with the exposed appearance of the P_3 roots as no images of the premolar roots were obtained on the radiographs. In both KNM-ER 403 and L.H.4 the P_4 is supported by mesial and distal roots which are bifurcated to within the cervical third of root height. The same picture does not appear to apply to KNM-ER 730. No radiographic image of the P_4 roots of this specimen could be obtained. At the level of its exposure - this being apical to the level at which the right P_3 shows bifurcation, the right P_4 root cross-section is unbifurcated and mesiodistally compressed. However, clefts on the buccal and lingual borders of the root cross-section suggest that bifurcation may occur at a more apical level, in which case the resulting roots

would probably be closely approximated, but this is not certain.

In the remaining specimens - KNM-ER 725, KNM-ER 733, KNM-ER 1805, KNM-ER 3729 - the exact nature of the $P_{\bar{3}}$ roots is uncertain. The damaged, eroded and fragmentary $P_{\bar{3}}$ remnants of KNM-ER 725 and KNM-ER 733 appear to be more compatible with the presence of mesiobuccal and distal roots than with mesial and distal roots. As exposed on the specimen, each eroded $P_{\bar{3}}$ of KNM-ER 1805 comprises a single C-shaped root cross-section which is orientated more-or-less transversely in its lingual part but curves mesially in its buccal part to form a mesiobuccal component. This appearance is compatible with close apposition of mesiobuccal and distal roots - the bifurcation of the roots being present at a level lower than the exposed sections - though the roots appear reduced in comparison to other $P_{\bar{3}}$ specimens having mesiobuccal and distal roots. As a result of the mesiobuccal-distolingual orientation of the root cross-section, the roots might be better described as mesiobuccal and distolingual, and the specimen more properly assigned to group C (see below). Radiography of the premolar roots of KNM-ER 1805 did not provide images which were good enough to resolve this. The $P_{\bar{3}}$ of KNM-ER 3729 is clearly two-rooted - the root cross-section being apical to the level of bifurcation - and the appearance of the two roots is best interpreted as indicating the presence of mesiobuccal and distal roots. The diagnosis of mesial and distal roots to $P_{\bar{4}}$ is clearly indicated by the root cross-sections

of KNM-ER 725 and KNM-ER 3729, but is less clear in the case of KNM-ER 733. However, the locations of the pulp canals in the P_4 root cross-section of KNM-ER 733 indicate that the cross-section is aligned obliquely with respect to the mesiodistal axis and so is compatible with the presence of mesial and distal roots. Radiography of these specimens was of no assistance in the diagnosis of P_4 root form. Nor was it in the case of KNM-ER 1805 for which no assessment of P_4 root form could be made from the appearance of the specimen.

B. P_3 2R:M+D, P_4 2R:M+D

In some fossil hominids, both mandibular premolars are supported by mesial and distal roots. Each premolar has two mesiodistally compressed roots which are more-or-less parallel to each other and the level of bifurcation between the roots is high, i.e. within the cervical third or root height. Each root has two pulp canals, and the distal root tends to be displaced lingually with respect to the mesial root. The mesial root may be better developed bucally than lingually, while the distal root is invariably better developed lingually than buccally. Particularly in P_4, the displacement of the distal root and the relatively greater development of its lingual part may result in an asymmetric appearance to the root cross-section when exposed cervical to the level of bifurcation. The mesial root of P_4 may show a tendency toward root bifurcation. Depending on the state of preservation, this root form is identifiable for one or both of the mandibular premolars of the following fossil hominid

specimens: KNM-ER 729, KNM-ER 810A, KNM-ER 818, KNM-ER 1468, KNM-ER 1806, KNM-ER 3229, KNM-ER 3230, KNM-ER 3731, KNM-ER 3954 and the Peninj mandible. Other hominids which may belong to this group are KNM-ER 726 and KNM-ER 1802.

The cross-section through the left $P_{\overline{3}}$ roots of KNM-ER 1806 - which is apical to the level of bifurcation - clearly illustrates this $P_{\overline{3}}$ root form. The $P_{\overline{3}}$s of KNM-ER 3229, KNM-ER 3731 and KNM-ER 3954 also have mesial and distal roots - in these instances the root cross-sections are cervical to the level of bifurcation. The presence of mesial and distal roots to the $P_{\overline{3}}$s of the Peninj mandible was diagnosed radiographically. In other fossil hominid specimens, the diagnosis of mesial and distal roots to the $P_{\overline{3}}$ is less certain. Although damaged in varying degrees, the $P_{\overline{3}}$ regions of KNM-ER 726, KNM-ER 810A and KNM-ER 818 appear to indicate the presence of mesial and distal roots. The $P_{\overline{3}}$ root form of KNM-ER 1802 is also uncertain. The images of two roots can be seen on the lateral radiograph, but the image on the occlusal radiograph is too dense to assist in the diagnosis. A clue to the form of the $P_{\overline{3}}$ roots is provided by the exposed root cross-section of the left $P_{\overline{3}}$, which appears to be most compatible with the presence of mesial and distal roots.

For most fossil himinids in this group - KNM-ER 726, KNM-ER 729, KNM-ER 810A, KNM-ER 1468, KNM-ER 1806, KNM-ER 3229, KNM-ER 3230, KNM-ER 3731, KNM-ER 3954, Peninj - the $P_{\overline{4}}$ clearly has mesial and distal roots,

the diagnosis being based on direct and/or radiographic examination. Only for KNM-ER 818 and KNM-ER 1802 is the diagnosis less than certain. Lateral radiographs of these specimens indicate the presence of two roots to the P_4 - clearly in the case of the latter specimen, less clearly in the case of the former - which are assumed to be mesial and distal roots. Occlusal radiographs and direct observation were of no assistance in the assessment of the P_4s of these specimens.

C. P_3 2T, P_4 2R:M+D

The P_3 is two-rooted, and the roots are mesiobuccal and distolingual. In cross-section, the roots tend to be triangular-shaped, and the bifurcation between them runs from mesiolingual to distobuccal. Cervical to the level of bifurcation, which is not necessarily within the cervical third of root height but may be situated more apicalward, the root cross-section is single with its long axis running from mesiobuccal to distolingual and there may be indentations in the outline of the cross-section corresponding to the mesiolingual and distobuccal clefts. P_4 has mesial and distal roots which are mesiodistally compressed but the level of bifurcation tends to be displaced apicalward from the cervical third of root height. The mandibular premolar roots of the following fossil hominid specimens are of this form: KNM-ER 819, KNM-ER 1482, KNM-ER 1801, KNM-ER 1811, KNM-ER 3734, and O.H.51.

For the P_3s of KNM-ER 819, KNM-ER 1482, KNM-ER 1801 and KNM-ER 3734, the diagnosis of mesiobuccal and disto-

lingual roots is based on radiographic examination. For each of these specimens except KNM-ER 3734, a root cross-section through $P_{\overline{3}}$ is exposed on the specimen but this is single, being cervical to the level of bifurcation. The exposed $P_{\overline{3}}$ root cross-section of KNM-ER 1811 is also single and has a marked cleft at its mesiolingual corner. The diagnosis of mesiobuccal and distolingual roots for this $P_{\overline{3}}$ is not certain, as no assessment could be made radiographically, but was thought to be more compatible with the $P_{\overline{4}}$ root form than the presence of a single root.

For all these specimens except KNM-ER 1811, the presence of mesial and distal roots to $P_{\overline{4}}$ was clearly indicated by radiographic assessment. In some $P_{\overline{4}}$s - those of KNM-ER 819, KNM-ER 3734 and O.H.51 - the level of bifurcation is more apicalward than in others - those of KNM-ER 1482 and KNM-ER 1801 - occurring within the middle third of root height. The $P_{\overline{4}}$ of KNM-ER 1811 clearly has mesial and distal roots; the exposed $P_{\overline{4}}$ root cross-section is apical to the level of bifurcation so that two separate roots are visible.

D. $P_{\overline{3}}$ 1R, $P_{\overline{4}}$ 1R

Both $P_{\overline{3}}$ and $P_{\overline{4}}$ have roots which are effectively single, although apical bifurcation may be present. In the case of $P_{\overline{3}}$, a mesiolingual cleft, which may be identifiable radiographically or directly, indicates the presence of the root form known as Tomes' root. Fossil hominids from Koobi Fora, Laetoli and Olduvai Gorge have mandibular premolar roots of this type: KNM-ER 992, KNM-ER 1483, KNM-ER 1501, KNM-ER 1812,

KNM-ER 3889, L.H.10, L.H.14, O.H.7, O.H.13, O.H.16, O.H.22, O.H.23 and O.H.37.

Radiographs of KNM-ER 1483, KNM-ER 1501, O.H.13 and O.H.23 indicate that Tomes' root is present in the P_3s of these specimens. The P_3 root is exposed in cross-section on KNM-ER 1483 and KNM-ER 1501 and appears single with its long axis aligned obliquely from mesiobuccal to distolingual. In the latter specimen, the mesiolingual cleft clearly indents the border of the root cross-section. The P_3 roots of KNM-ER 1812, KNM-ER 3889 and L.H.10 are exposed in cross-section on the specimens, but could not be assessed radiographically. In each instance, the root cross-section is single, has a C-shaped pulp and is clearly indented at its mesiolingual corner by a cleft. These features are compatible with the presence of Tomes' root, but what is uncertain is whether or not bifurcation occurs at a more apical level. Tomes' root is also clearly present in the isolated P_3s of L.H.14 and O.H.16. Radiographically, the P_3s of O.H.22 and O.H.37 appear single-rooted - Tomes' root may be present in the latter specimen but the radiographic image is unclear. Although included in this category (particularly on the basis of P_4 root form), KNM-ER 992 and O.H.7 have P_3s which are not as reduced in root form as the previous specimens. These P_3s show clear bifurcation into mesiobuccal and distolingual roots which, radiographically, appear separate for about the apical third of root height in the case of O.H.7 and for about half the root height in the case of KNM-ER 992.

Radiographic examination of the $P_{\overline{4}}$s of KNM-ER 992, KNM-ER 1483, KNM-ER 1501, O.H.7, O.H.13, O.H.22, O.H.23 and O.H.37 shows them to be single-rooted. The $P_{\overline{4}}$ root appears apically bifurcated in KNM-ER 1483 and KNM-ER 1501, and is possibly so in O.H.7 but the $P_{\overline{4}}$ roots of this specimen are incomplete. In the other specimens except KNM-ER 992, O.H.13 and O.H.22, the $P_{\overline{4}}$ root is probably marked by a cleft. The isolated $P_{\overline{4}}$s of O.H.16 are also single-rooted, but the difference between the right and left teeth shows that variation may be found within an individual. The root of the right tooth is marked by a longitudinal groove for most of the height of the lingual surface; the lingual root surface of the left tooth is interrupted by a cleft which penetrates into the root. The root form of the left $P_{\overline{4}}$ of L.H.14 is uncertain as part of the root is missing, but the observed root morphology is most compatible with a classification of 1R, though bifurcation may have been present at a more apical level. The $P_{\overline{4}}$s of KNM-ER 3889 and L.H.10 are classified as 1R though this is not certain as it is based only on the root cross-sections as exposed on the specimens. The cross-sections are single, but marked by root grooves or clefts which may lead to bifurcation at a more apical level.

iii) Summary

This radiographic study has shown that, with one exception, the maxillary premolars of the pongids are typically three-rooted, the roots being similar in form to those of maxillary molars. According to this study,

the $P^{\underline{4}}$ of Pan is typically two-rooted, as noted previously by Duckworth (1923) in contrast to the observations of other authors (Owen, 1840-45; Scott & Symons, 1974) who have described maxillary premolars as typically three-rooted in all the pongids. The occurrence of two-rooted maxillary premolars in Pan has also been recorded by Colyer (1936). In this study, two-rooted maxillary premolars were also recorded in Pongo, but not in Gorilla. In Pongo, they occur in $P^{\underline{3}}$ and $P^{\underline{4}}$ with a frequency of just less than 10% (similar to that documented for the $P^{\underline{3}}$ of Pan).

Previous observations that the mandibular premolars are typically two-rooted in the pongids are supported by the results of this radiographic study. Usually, the pongid $P_{\overline{3}}$ is supported by mesiobuccal and distal roots, and the $P_{\overline{4}}$ by mesial and distal roots. However, this study has shown that the $P_{\overline{3}}$ of Pongo and of Pan may occasionally have roots of reduced form, appearing, at least radiographically, to be single. Fusion of the roots in Pan mandibular premolars has been commented upon previously (James, 1960; Tomes, 1923).

In modern man, premolar root number differs from that observed in the pongids. In the modern human sample used in this study, both maxillary premolars are typically single-rooted - $P^{\underline{4}}$ (100%) to a greater degree than $P^{\underline{3}}$ (83%) - and these results agree with recorded observations that root bifurcation is more frequently encountered in $P^{\underline{3}}$ than in $P^{\underline{4}}$. The incidence of single-rooted maxillary premolars in the Romano-British ($P^{\underline{3}}$=82%, $P^{\underline{4}}$=100%) and in the Australian Aborigines ($P^{\underline{3}}$=85%, $P^{\underline{4}}$=100%) appears high

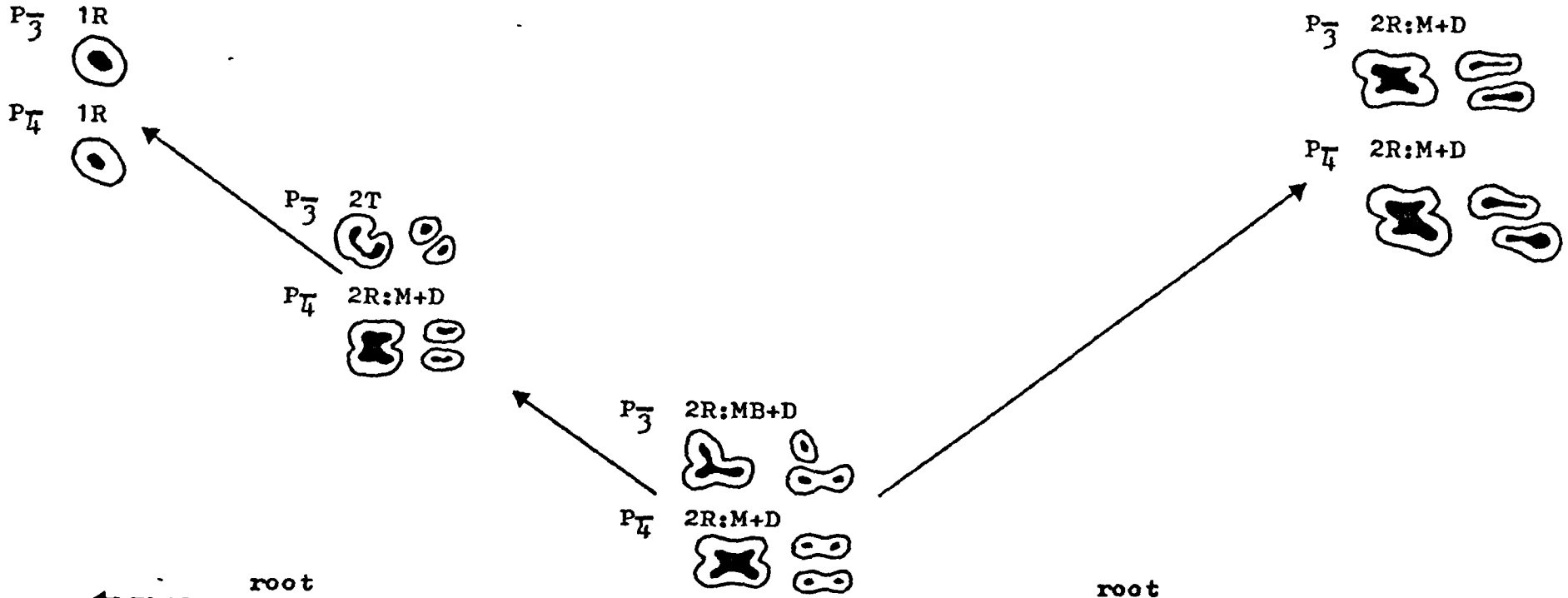
in comparison to most published frequencies for Europeans ($P^{\underline{3}}$=29-56%, $P^{\underline{4}}$=46-93%) and for Australian Aborigines ($P^{\underline{3}}$=31%, $P^{\underline{4}}$=83%) (Abrahams, 1946-47; Campbell, 1925; Fabian, 1928, cited by Pedersen, 1949; Ingle, 1965, cited by Barker et al, 1973; Selmer-Olsen, 1949; Visser, 1943b). However, the incidences recorded in this study almost certainly represent an overestimation which has resulted from the difficulty sometimes encountered in distinguishing on the radiographs between one-rooted and two-rooted premolars because of superimposition. In addition, the discrepancies in incidence between this and other studies may partly reflect difference in sample size - the sample used in this study is small in comparison to some published studies. Differences in methodology, such as the use of different definitions for root number classification, can result in significantly different root number frequencies (Turner, 1981).

In agreement with previous observations on root number in modern man (Barker et al, 1973; Duckworth, 1923; Scott & Symons, 1974; Sprinz, 1953), the mandibular premolars are typically single-rooted in the modern human sample used in this study. One case of a two-rooted $P_{\underline{3}}$ was documented, but this root form was not recorded in the $P_{\underline{4}}$ sample, lending some support to the observation (Brabant et al, 1953; Goh, 1957; Sprinz, 1953) that $P_{\underline{3}}$ exhibits greater variation in root morphology than $P_{\underline{4}}$. The incidence of two-rooted mandibular premolars is comparable to that ($P_{\underline{3}}$=1.2%, $P_{\underline{4}}$=0.2%) reported for the Norwegian Lapps (Selmer-Olsen, 1949).

In the fossil hominid sample (Fig.44), there is considerable variation in mandibular premolar root form, particularly for P_3. Fossil hominid P_3s may have mesial and distal roots, or mesiobuccal and distal roots, or mesiobuccal and distolingual roots, or a single root incorporating Tomes' root form, while P_4 root form is restricted to either mesial and distal roots or to a single root. However, for neither premolar are these categories discrete; they represent typical expressions within a continuum of root form.

The interpretation of mandibular premolar root form in the Hominidae necessitates, firstly, the identification of the region of the continuum which represents the ancestral or primitive mandibular premolar root-form. The results of studying the extant pongids suggest that the probable ancestral mandibular premolar root form was that in which P_3 has mesiobuccal and distal roots, and P_4 has mesial and distal roots. This root form is typical for the modern pongids and also seems to have been, as far as it has been able to be determined, for Miocene hominoids (Ward, 1979). The presence of this root form in some of the earliest hominids, in common with the pongids, supports its acceptance as the primitive pattern for the Hominidae. If this outlined premolar root form is accepted as the primitive condition, then it is clear that there must have been a pathway of root reduction leading to the mandibular premolar root form typical for modern man, in whom both mandibular premolars are typically single rooted as documented by this and many other studies.

Fig. 44 : Mandibular premolar root form in the fossil hominid sample



992 ?1811 819 ?1805 ?730 L.H.4 403 ?725 3731 ?726 ?1802 3954 729
1483 O.H.7 ?1812 1482 ?733 ?810A 1468
1501 ?3889 1801 ?3729 ?818 1806
L.H.14 ?L.H.10 3734 3229
O.H.13 O.H.51 3230
O.H.16 Peninj
O.H.22
O.H.23

However, when the mandibular premolar roots of the fossil hominid sample are examined, it is clear that not all specimens can be fitted into a scheme of root reduction. In order to explain completely the variation of mandibular premolar root form in the fossil hominid sample, it is proposed (Fig.44) that, collateral with the trend toward root reduction, there has been a trend toward a premolar root morphology which, as it recalls the form found in mandibular molars, may be termed 'root molarisation', and that this trend culminates in the mandibular premolar root form found in the 'hyper-robust' East African australopithecines. Details of mandibular premolar root form and the pathways of root reduction and root molarisation in the early fossil hominids will be outlined and discussed later (Chapter 11).

Part III

Chapter 10 : The root and crown dimensions and indices in the fossil hominid sample

i) Neck mesiodistal diameter

ii) Location of bifurcation

iii) Root height

iv) Root mesiodistal diameter

v) Height of bifurcation

vi) Root angulation

vii) Crown dimensions

viii) Summary

Chapter 10 : The root and crown dimensions and indices in the fossil hominid sample

In the fossil hominid sample, root dimensions were available only for the mandibular dentition and so the assessment which follows is limited to these teeth, being based primarily on the cheek-teeth as the anterior dentition is so poorly represented in the sample. The metrical assessment of the fossil hominid sample was conducted by examining root and crown size in the groups of fossil hominids formed by categorizing the specimens according to their mandibular premolar root form, as described in the previous chapter. Statistical summaries were computed for the root and crown dimensions and indices in each group, and these are given in Appendix M. The values of the root and crown dimensions and indices for the individual specimens are given in Appendix K.

Taken as a whole, the fossil hominid sample displays greater variability for many dimensions and indices of the mandibular cheek-teeth than does any of the comparative samples for the corresponding measure. This is not so for the mandibular anterior dentition, but the sample sizes are very small for most of these dimensions. Of the mandibular cheek-teeth, it is particularly $P_{\overline{4}}$ which exhibits high variability - nearly all root and crown dimensions and indices measured for this tooth are more variable in the fossil hominid sample than in any of the comparative samples. For each of the mandibular molars, about half the dimensions and indices are more variable in the fossil hominid sample than in any of the comparative samples. Of the dimensions and indices, the variability of

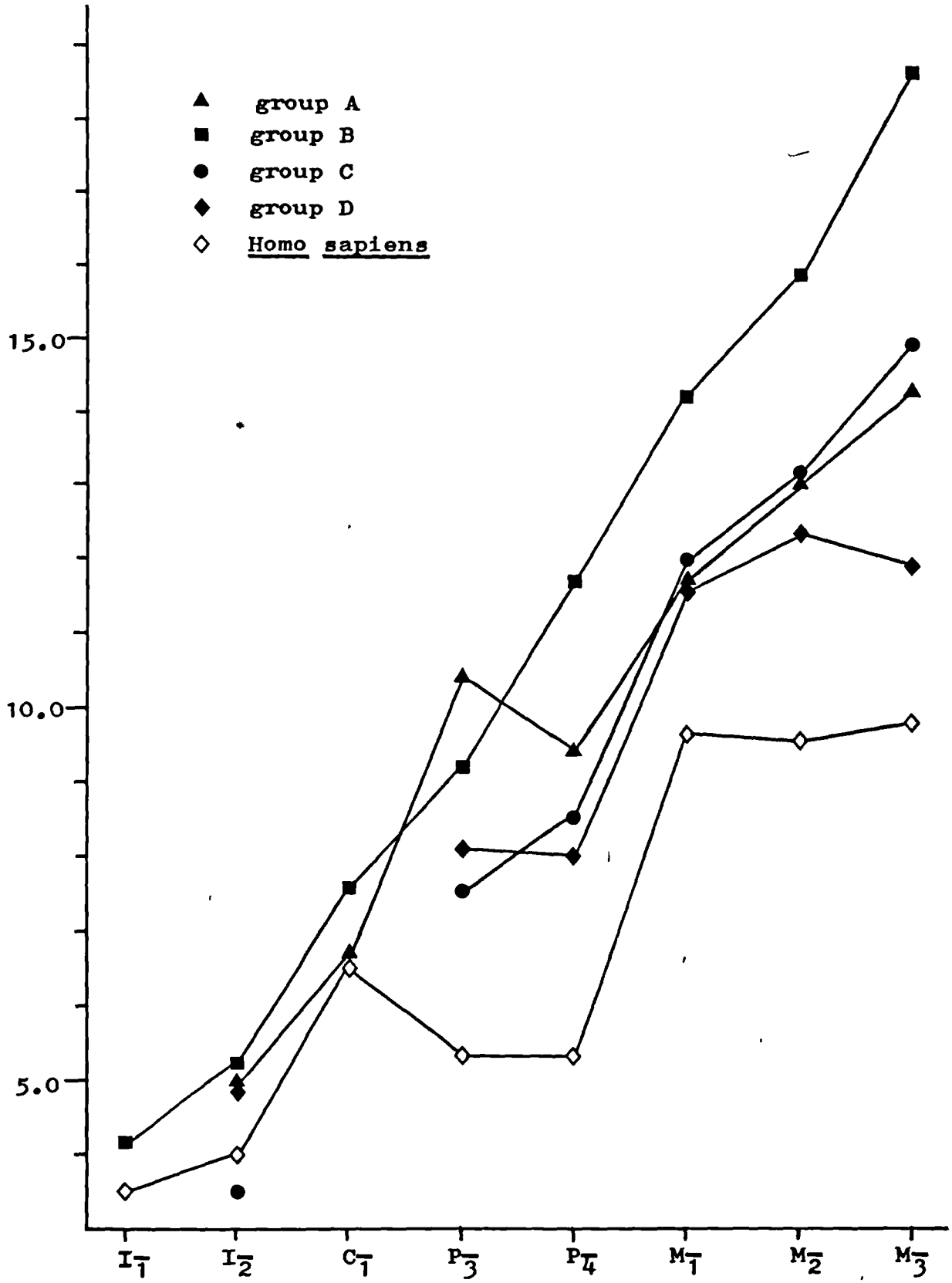
neck mesiodistal diameter and the crown dimensions in the fossil hominid sample exceeds that recorded for any of the comparative samples for most of the cheek-teeth, though in some instances to no very great degree.

i) Neck mesiodistal diameter

The statistical summary of neck mesiodistal diameter in the fossil hominid groups is given in Appendix M(i). Of the fossil hominid groups, only in group A does the value of the coefficient of variation for neck mesiodistal diameter suggest greater variability than found in any of the comparative samples. This applies for the neck mesiodistal diameters of $P_{\overline{4}}$ and $M_{\overline{3}}$. The $P_{\overline{4}}$ neck mesiodistal diameter shows considerable variation (C.V.=17.0) from the small size of L.H.4 (7.8, 8.4) to the large size of KNM-ER 403 (10.1) and KNM-ER 725 (11.3). However, for the $M_{\overline{3}}$ neck mesiodistal diameter, L.H.4 (14.2) is comparable in size to KNM-ER 725(14.7). The high value of the coefficient of variation for this dimension (C.V. = 13.6) in group A reflects the difference in size between KNM-ER 730 (11.7) and KNM-ER 733 (16.4).

The mean values of mandibular neck mesiodistal diameter in the fossil hominid groups are plotted out in Fig. 45. In group A, the $P_{\overline{3}}$ neck mesiodistal diameter appears greater than the $P_{\overline{4}}$ neck mesiodistal diameter - a pattern seen in all the comparative pongid samples. However, only two specimens - L.H.4 and KNM-ER 403 - contribute to the $P_{\overline{3}}$ sample, and only in L.H.4 is the $P_{\overline{3}}$ diameter (10.6) greater than the $P_{\overline{4}}$ diameter (7.8, 8.4). In KNM-ER 403, the $P_{\overline{3}}$ (10.1) and $P_{\overline{4}}$ (10.1) neck

Fig. 45 : Mean values of mandibular neck mesiodistal diameter in the fossil hominid groups



mesiodistal diameters are similar. In group B, neck mesiodistal diameter steadily increases in size from $I_{\overline{1}}$ to $M_{\overline{3}}$. The molar neck mesiodistal diameters, and also that of $P_{\overline{4}}$, are noticeably larger in this group than in the other fossil hominid groups. In groups A,C and D, the $M_{\overline{1}}$ neck mesiodistal diameter is very similar, and groups A and C also have similar diameters for the remaining molars. Group D differs from groups A and C particularly in the reduced size of the $M_{\overline{3}}$ neck mesiodistal diameter, and in group D the $P_{\overline{3}}$ neck mesiodistal diameter ($\overline{X}$=8.1) is similar in size to the $P_{\overline{4}}$ neck mesiodistal diameter ($\overline{X}$=8.0) - a pattern seen also in the comparative Homo sapiens sample.

ii) Location of bifurcation

The statistical summary for location of bifurcation in the fossil hominid groups is given in Appendix M(ii), that for location of bifurcation index in Appendix M(x). In the fossil hominid groups, the value of the coefficient of variation for location of bifurcation and for the location of bifurcation index is generally less than the maximum recorded in the comparative samples. Only in group B is greater variability suggested in a fossil hominid group than found in a comparative sample, and then only for the $P_{\overline{4}}$ location of bifurcation. In this group, the coefficient of variation (15.3) reflects the size difference between KNM-ER 729 (6.8) and KNM-ER 3230 (6.8) on the one hand and KNM-ER 3954 (4.4) on the other.

The mean values of location of bifurcation and location of bifurcation index in the fossil hominid groups are plotted out in Figs 46 and 47, respectively. As noted in the comparative

Fig. 46 : Mean values of mandibular location of bifurcation in the fossil hominid groups

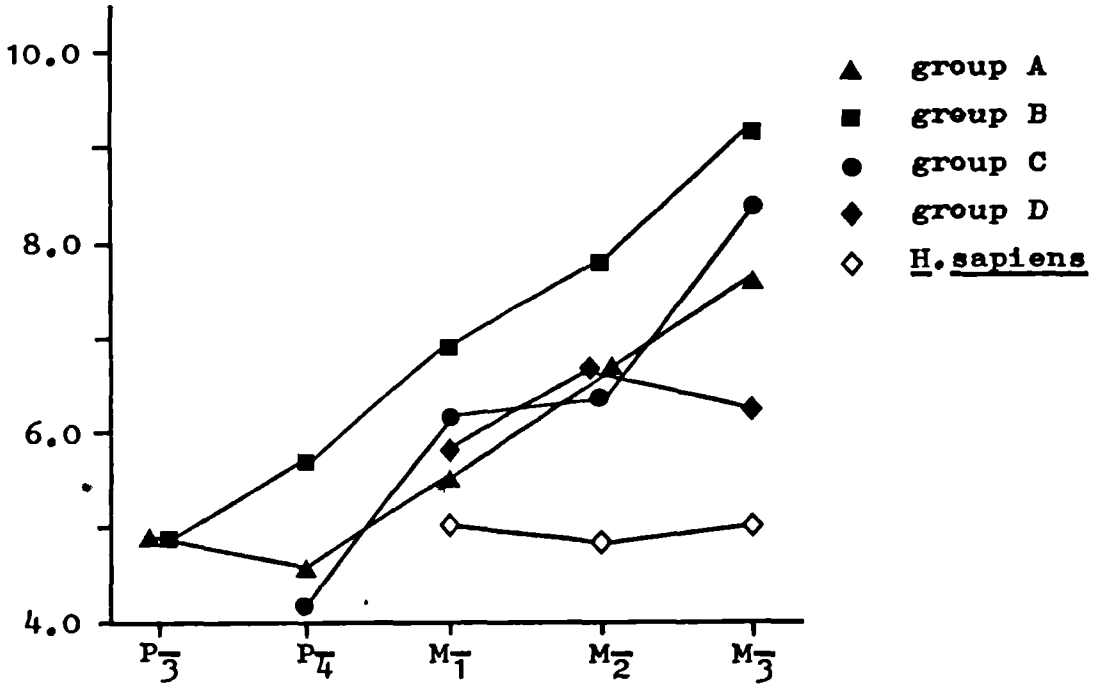
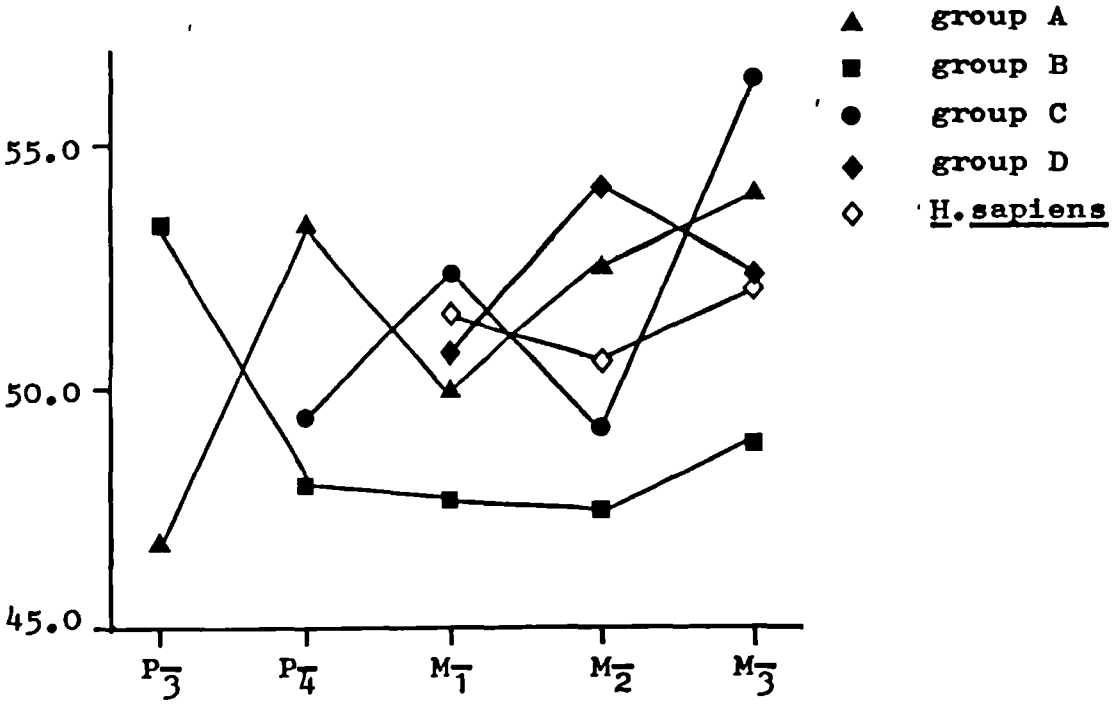


Fig. 47 : Mean values of location of bifurcation index in the mandibular teeth of the fossil hominid groups



samples, in the fossil hominid groups the mean values of location of bifurcation indicate a pattern similar to that seen for neck mesiodistal diameter. For corresponding teeth, location of bifurcation appears larger in group B than in groups A,C and D, which appear similar for this dimension, particularly in $M_{\overline{1}}$ and $M_{\overline{2}}$. No clear pattern appears to underlie the mean values of the location of bifurcation index in the fossil hominid groups. It may be that, for $P_{\overline{4}}$ to $M_{\overline{3}}$, the bifurcation is positioned relatively slightly more mesially in group B than in the other groups.

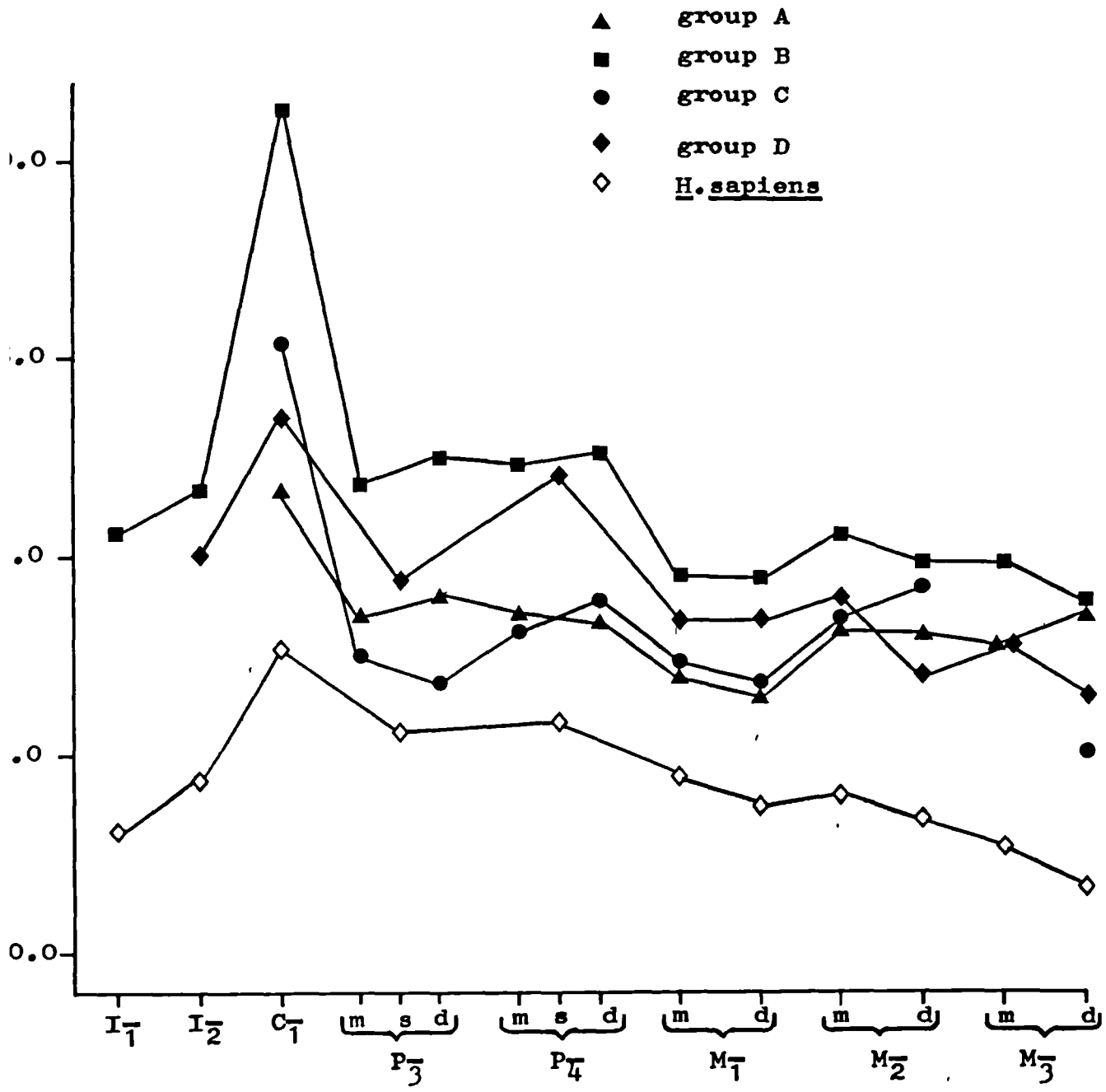
iii) Root height

Statistical summaries for actual root height and projected root height in the fossil hominid groups are given in Appendices M(iii) and M(iv), respectively. With only a few exceptions, in the fossil hominid groups the coefficient of variation for actual root height is comparable in value to the maximum recorded in the comparative samples for corresponding roots. Greater variability in the fossil hominid groups than in the comparative samples is suggested only in groups A and C, for the root heights of $M_{\overline{1}}$ and $M_{\overline{2}}$ in the former group and for those of $M_{\overline{1}}$ in the latter. In group A, the high value of the coefficient of variation reflects the difference in root height between KNM-ER 730 on the one hand ($M_{\overline{1}}m$=21.4, $M_{\overline{1}}d$=21.0, $M_{\overline{2}}m$=24.6, $M_{\overline{2}}d$=24.1) and L.H.4 (right) on the other ($M_{\overline{1}}m$=13.8, $M_{\overline{1}}d$=12.6, $M_{\overline{2}}m$=13.5, $M_{\overline{2}}d$=13.3). A similar difference in $M_{\overline{1}}$ root heights between O.H.51 ($M_{\overline{1}}m$=21.3, $M_{\overline{1}}d$=20.5) and KNM-ER 1801 ($M_{\overline{1}}m$=13.5, $M_{\overline{1}}d$=13.5) underlies the high value of the coefficient of variation for the $M_{\overline{1}}$ root heights in group C.

All values of the coefficient of variation for actual root height in the fossil hominid groups B and D are smaller than or comparable to the values recorded in the comparative samples.

The mean values of actual root height in the fossil hominid groups are plotted out in Fig. 48. Of all the groups, root height is greatest in group B, and particularly the $C_{\overline{1}}$ root appears long - though represented by only two specimens (KNM-ER 729, KNM-ER 3230) - being comparable in mean value ($\bar{X}$=31.2) to the modern pongids ($\bar{X}$: Gorilla=33.1, Pan=28.6, Pongo=34.6; Fig.14; Appendix D(iii)). As in the pongids, $C_{\overline{1}}$ root height is noticeably greater than the incisor and premolar root heights, but again the sample sizes are small, particularly for the incisors and $P_{\overline{3}}$. The molar roots are shorter than the premolar roots, with the $M_{\overline{2}}$ roots appearing slightly longer than those of $M_{\overline{1}}$ and $M_{\overline{3}}$. Overall, root height is slightly shorter in group D than in group B, but particularly $C_{\overline{1}}$ root height is shorter ($\bar{X}$=23.5), approaching the height of the premolar roots ($\bar{X}$: $1RP_{\overline{3}}$=19.3, $1RP_{\overline{4}}$=22.1). In the modern Homo sapiens sample, $C_{\overline{1}}$ root height is only slightly greater than premolar root height, unlike the pattern seen in the pongids, and both premolar roots are similar in height. In group D, while $P_{\overline{4}}$ root height (Fig.48) appears only slightly less than $C_{\overline{1}}$ root height, $P_{\overline{3}}$ root height appears noticeably less. To some degree, this pattern reflects the fact that not all group D specimens contribute to the $C_{\overline{1}}$, $1RP_{\overline{3}}$ and $1RP_{\overline{4}}$ samples. Only two specimens (KNM-ER 1501, O.H.22) contribute to each of these samples, and in these specimens the premolar root heights are similar and slightly less than $C_{\overline{1}}$ root height. In O.H.13, the $P_{\overline{3}}$ and $P_{\overline{4}}$ root heights are similar. In other

Fig. 48 : Mean values of mandibular actual root height in the fossil hominid groups



specimens (KNM-ER 992, KNM-ER 1483), the pattern of $C_{\overline{1}}$ root height being only slightly greater than premolar root height is present, irrespective of the fact that $P_{\overline{3}}$ and $P_{\overline{4}}$ differ slightly in root form in these specimens. Generally, root height is similar in groups A and C, and shorter than in the other fossil hominid groups.

iv) Root mesiodistal diameter

Statistical summaries for root mesiodistal diameter and for the root robusticity index in the fossil hominid groups are given in Appendices M(v) and M(xi), respectively. In group A, the values of the coefficient of variation for the distal root mesiodistal diameters of $P_{\overline{4}}$ and $M_{\overline{1}}$ are greater than the maximum recorded in any of the comparative samples for the corresponding root, reflecting the difference in size between KNM-ER 403 on the one hand ($2RP_{\overline{4}}d$=5.1, $M_{\overline{1}}d$=6.0) and L.H.4 ($2RP_{\overline{4}}d$=3.4, 3.7; $M_{\overline{1}}d$=4.0, 4.0) and KNM-ER 730 ($M_{\overline{1}}d$=4.6) on the other. In the other fossil hominid groups, the values of the coefficient of variation for the root mesiodistal diameters are smaller than or comparable to those recorded for the comparative samples.

In each of the fossil hominid groups except group B, the value of the coefficient of variation for the robusticity of a root suggests greater variability in the hominid group than in any of the comparative samples. This applies in group A for the $M_{\overline{3}}$ mesial root - the robusticity of this root in KNM-ER 733 (28.4) being intermediate between KNM-ER 730 (21.9) and the more robust L.H.4 (35.8), and in group C for the $P_{\overline{4}}$ distal root, this root being more robust in KNM-ER 819 (30.4)

than in the other specimens included in this group (KNM-ER 1482=18.1, KNM-ER 1801=22.6, KNM-ER 3734=19.4, O.H.51=17.7). In group D, the robusticity of the $1RP^{\overline{4}}$ root varies between 21.6 for KNM-ER 992 and 39.1 for KNM-ER 1501.

The mean values of root mesiodistal diameter and root robusticity in the fossil hominid groups are plotted out in Figs 49 and 50, respectively. The root mesiodistal diameters of comparable postcanine roots are essentially similar in the fossil hominid groups A, C and D, appearing smaller, with the exception of the $P_{\overline{3}}$ mesial root, than corresponding roots in group B. In particular, the $P^{\overline{4}}$, $M_{\overline{2}}$ and $M_{\overline{3}}$ root mesiodistal diameters appear larger in group B than in the other groups. In the hominid groups, there is an overall trend for root mesiodistal diameter to increase from the $P_{\overline{3}}$ mesial root to the $M_{\overline{3}}$ distal root. However, the single-rooted premolars of group D form an exception to this generalisation as the root mesiodistal diameters of these single roots are much larger than those of any of the molar roots, and thus these specimens depart from the pattern seen in the modern H.sapiens sample in which the premolar root mesiodistal diameters are of much the same size as the molar root mesiodistal diameters. Values for $C^{\overline{1}}$ root mesiodistal diameter are available only for hominid groups A and B. In group A, this dimension (5.1) appears similar in size to the mean value (5.4) recorded for the modern H.sapiens sample, being smaller than in group B (6.7), but in both hominid groups the root mesiodistal diameter of the $C^{\overline{1}}$ appears similar in size to that of the $M_{\overline{2}}$ distal or $M_{\overline{3}}$ mesial root. This pattern is unlike that found in the comparative samples, particularly in the pongids, where the root mesiodistal diameter of the $C^{\overline{1}}$ far exceeds that of any

Fig. 49 : Mean values of mandibular root mesiodistal diameter in the fossil hominid groups

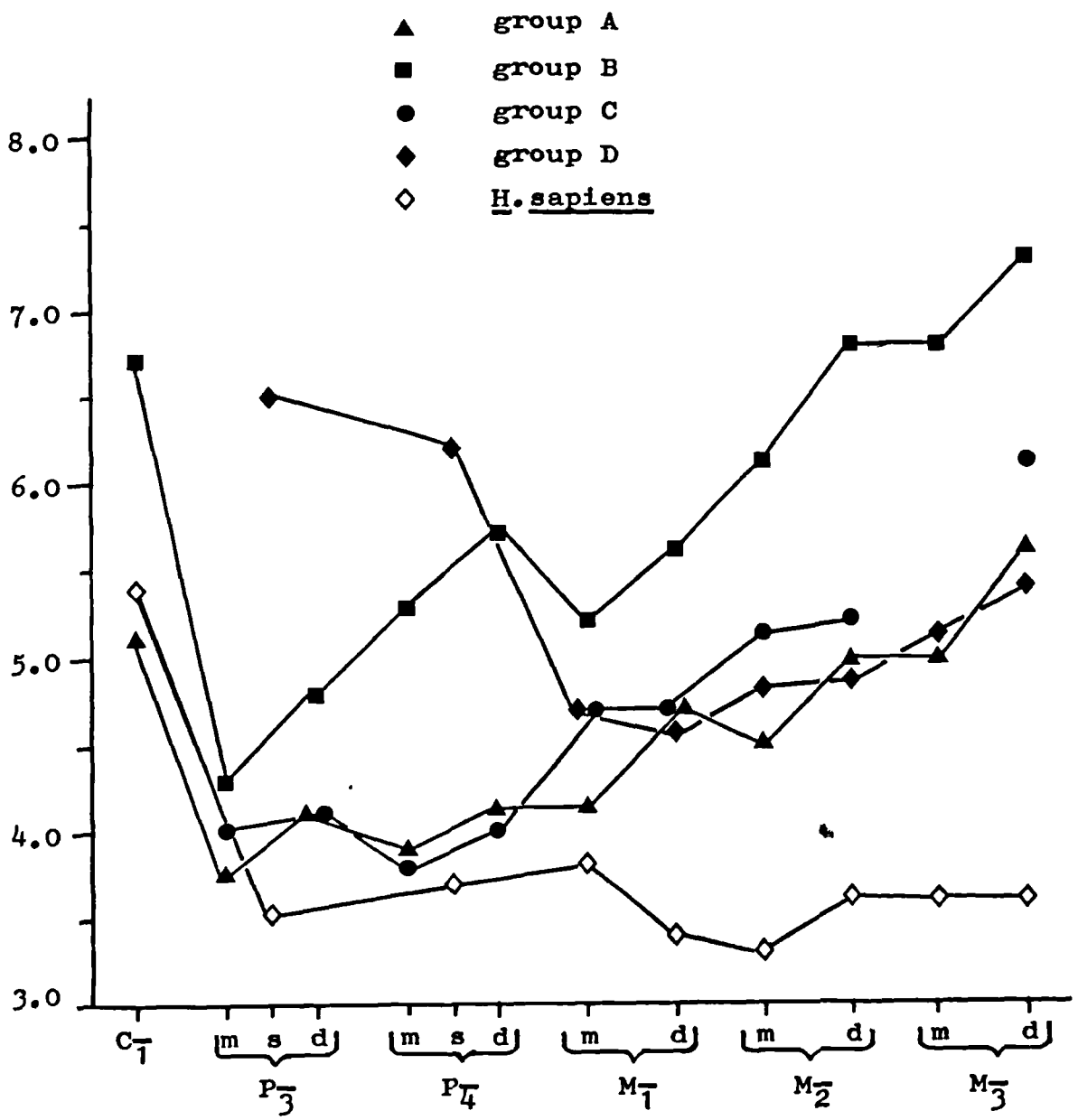
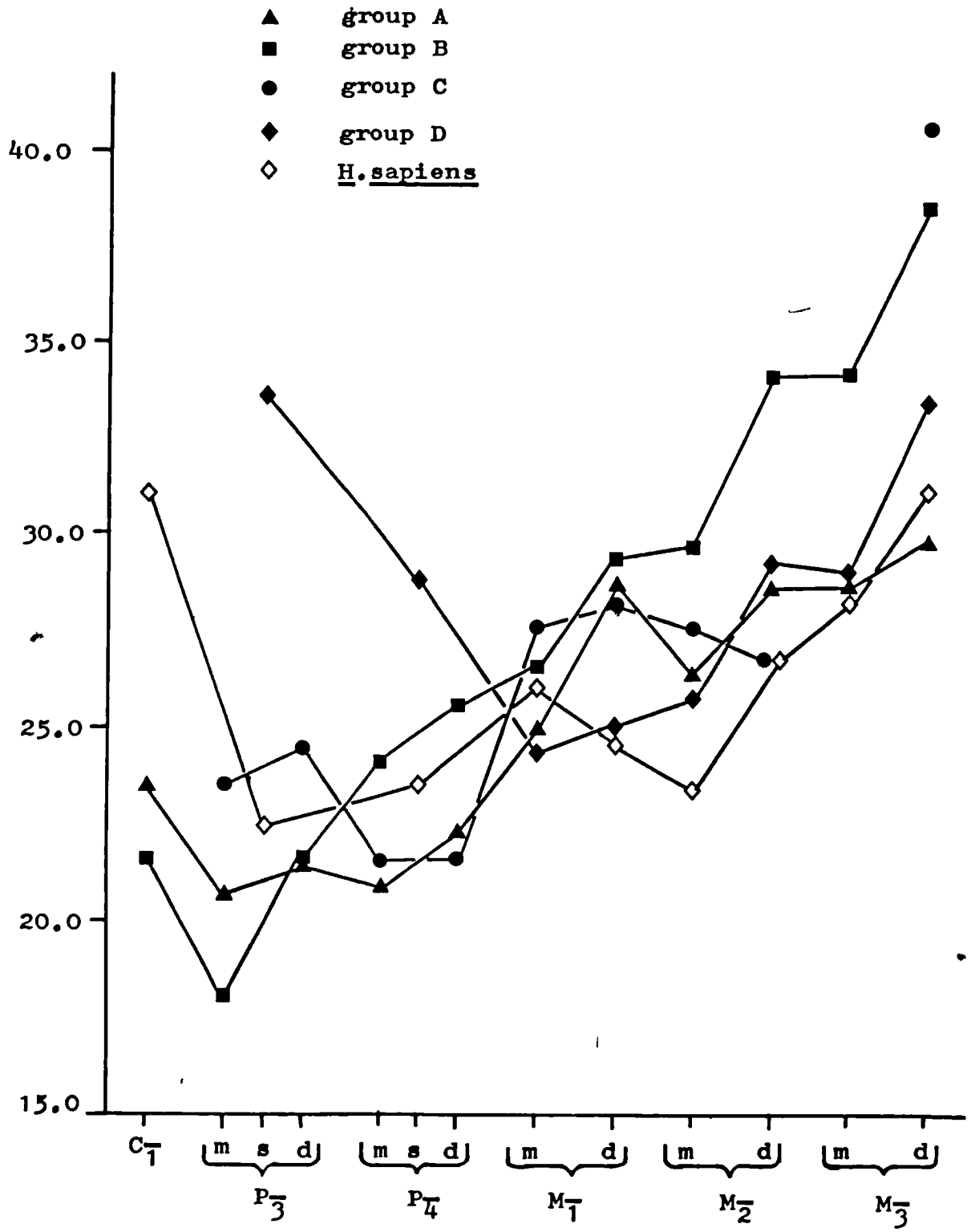


Fig. 50 : Mean values of the root robusticity index for the mandibular roots of the fossil hominid groups



postcanine root.

There are few points to be made about root robusticity in the fossil hominid groups. Generally, the robusticity of the roots is loosely similar in the fossil hominid groups, though the $P_{\overline{4}}$, $M_{\overline{2}}$ - particularly the distal root - and the $M_{\overline{3}}$ roots appear more robust in group B than in the other groups. Molar root robusticity in groups A, C and D is generally similar to that recorded for the modern H.sapiens sample, while the robusticity of the single-rooted premolars of group D far exceeds that of the same roots in the modern sample. The $C_{\overline{1}}$ root is less robust in the fossil hominid groups A (23.4) and B ($\overline{X}$=21.6) than in the modern H.sapiens ($\overline{X}$=31.0), Gorilla ($\overline{X}$=33.3) or Pan ($\overline{X}$=30.3) samples, being closest to the more gracile root of the Pongo sample ($\overline{X}$=25.8).

v) Height of bifurcation

Statistical summaries for height of bifurcation and for the height of bifurcation index in the fossil hominid groups are given in Appendices M(vi) and M(xii), respectively. In the fossil hominid groups A and D, the value recorded for the coefficient of variation for some molar heights of bifurcation exceeds the maximum documented for the corresponding molar in any of the comparative samples. In group A, this applies for the $M_{\overline{2}}$ and $M_{\overline{3}}$ heights of bifurcation, reflecting the difference between L.H.4 ($M_{\overline{2}}$=2.5, $M_{\overline{3}}$=2.5) on the one hand and KNM-ER 730 ($M_{\overline{2}}$=5.0, $M_{\overline{3}}$=5.4) and KNM-ER 733 (6.4) on the other. In group D, height of bifurcation varies widely for each of the mandibular molars. The value of the coefficient

Fig. 51 : Mean values of height of bifurcation in the mandibular teeth of the fossil hominid groups

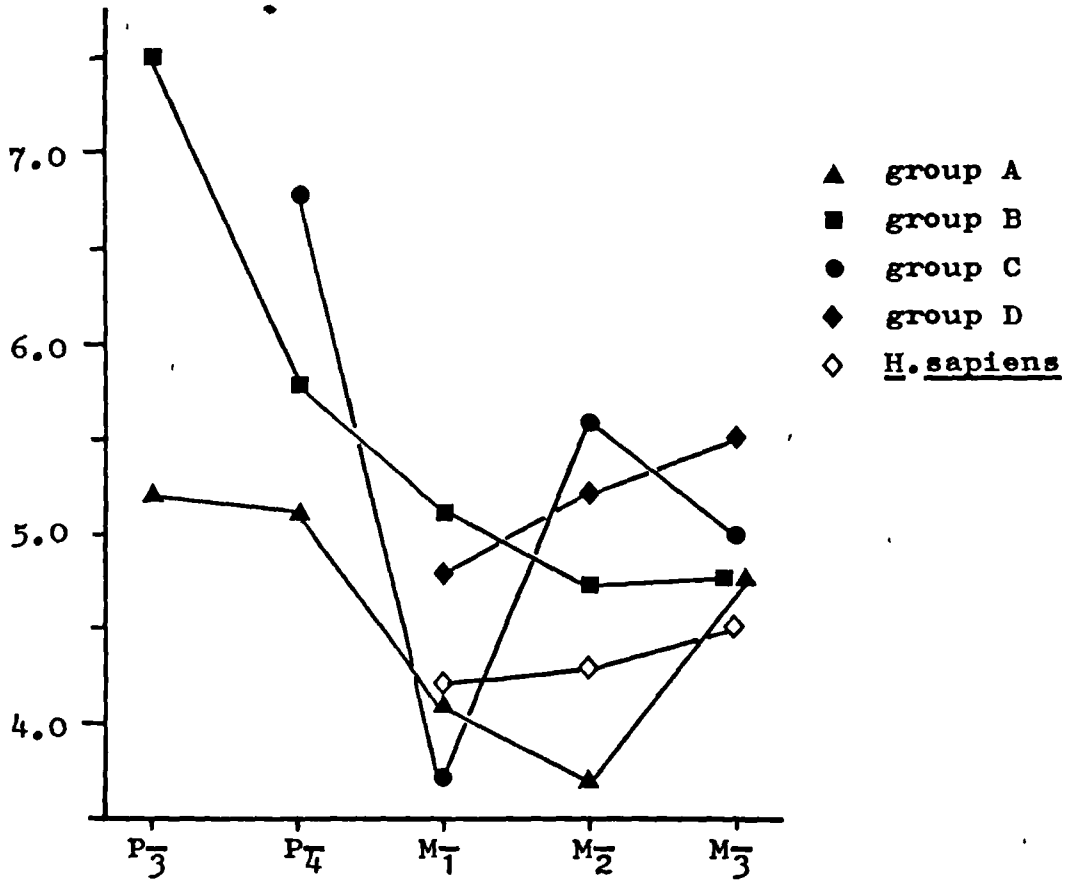
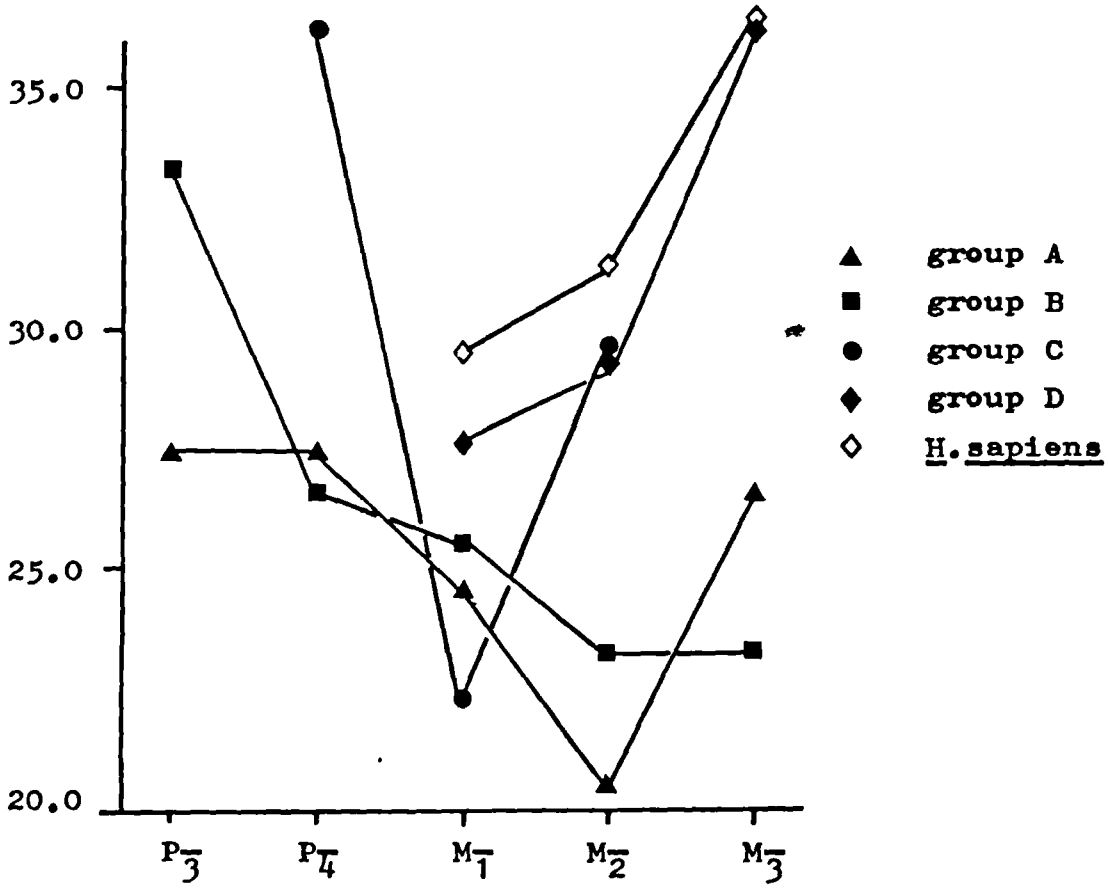


Fig. 52 : Mean values of the height of bifurcation index in the mandibular teeth of the fossil hominid groups



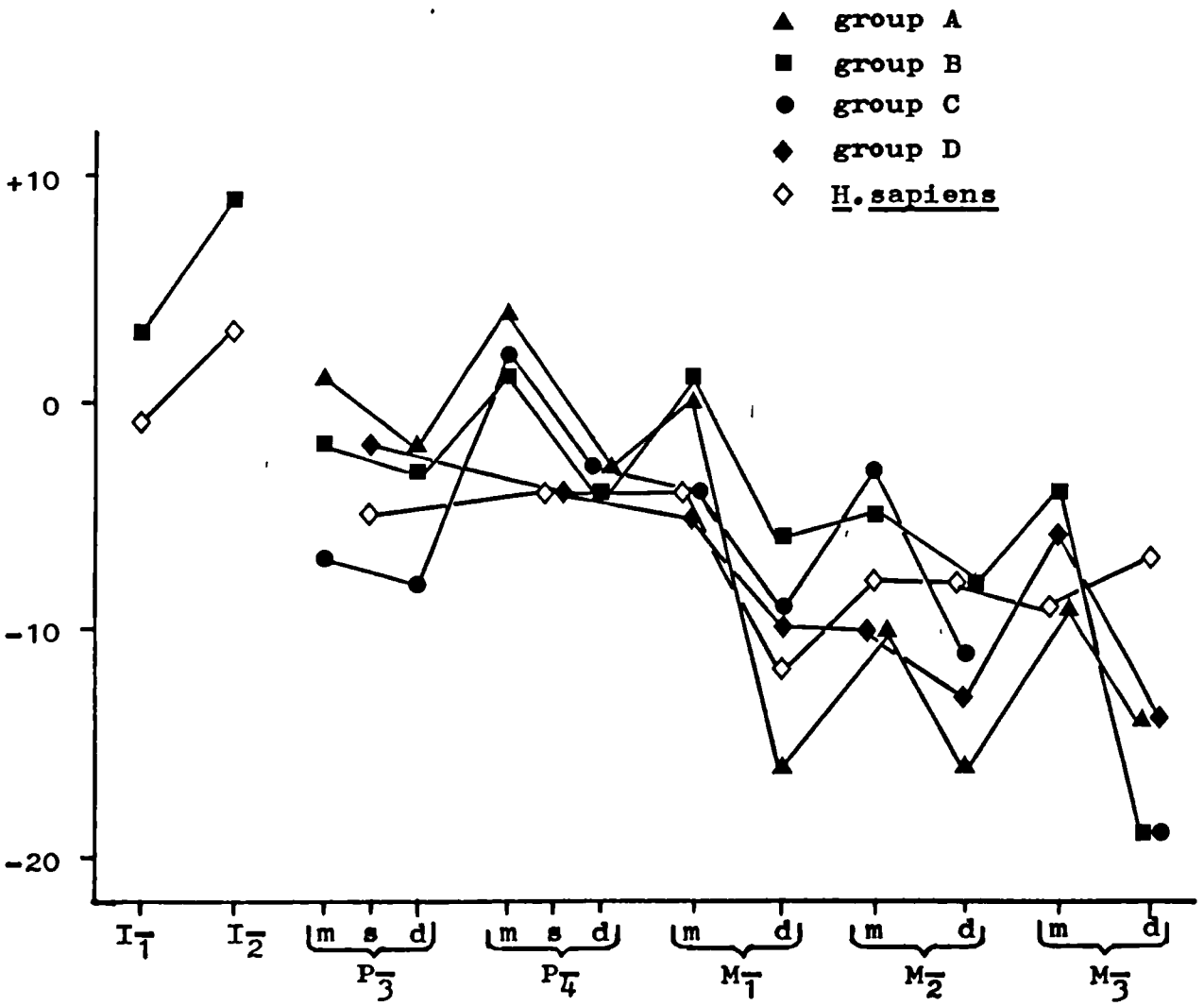
of variation for the height of bifurcation index may be very large in the fossil hominid groups, but in none of them is this suggestive of greater variability than found in the comparative samples.

The mean values of mandibular height of bifurcation and height of bifurcation index in the fossil hominid groups are plotted out in Figs 51 and 52, respectively. There is little worthy of note in the absolute values of height of bifurcation in the fossil hominid groups, but some of the index values attract comment. Although the molar heights of bifurcation are actually larger in group D than in the modern H.sapiens sample, the mean values of height of bifurcation index indicate that, for each molar, the relative height of the bifurcation is very similar in these two groups, being slightly greater in the modern sample. In fact, the molar heights of bifurcation are relatively larger in the modern H.sapiens sample than in any of the fossil hominid groups.

vi) Root angulation

Statistical summaries for mandibular root angulation and for root divergence in the fossil hominid groups are given in Appendices M(vii) and M(xiii), respectively, and the mean values of mandibular root angulation and root divergence in the fossil hominid groups are plotted out in Figs 53 and 54, respectively. Incisor root angulation is represented only by KNM-ER 3230 (group B) and this is similar to the modern pongids and Homo sapiens in that the $I_{\frac{2}{}}$ root shows more mesial angulation than the more or less vertically orientated $I_{\frac{}{1}}$ root. Comparison of root angulation in the mandibular cheek teeth

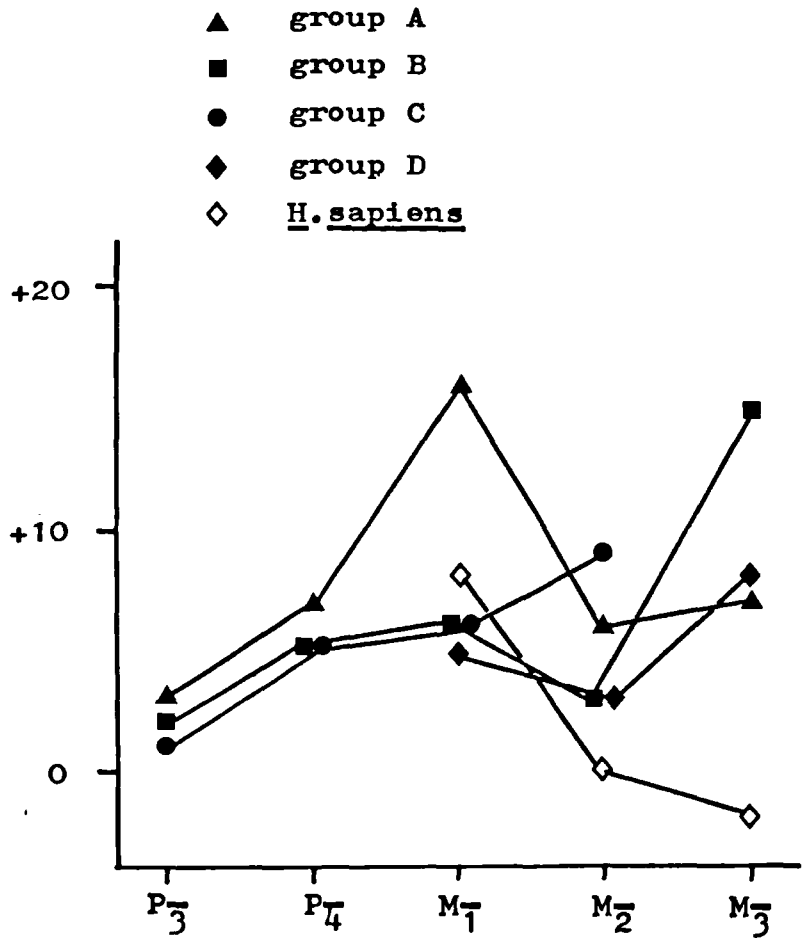
Fig. 53 : Mean values of mandibular root angulation in the fossil hominid groups



\+ = mesial angulation

\- = distal angulation

Fig. 54 : Mean values of root divergence in the mandibular teeth of the fossil hominid groups



\+ = root divergence

\- = root convergence

does not reveal any clear pattern of differences between the fossil hominid groups. In particular, the angulation of the $P_{\overline{4}}$ roots is very similar. In the hominid groups, the distal root of each two-rooted cheek tooth shows greater distal angulation than the mesial root. This pattern is found also in the pongids, for $P_{\overline{4}}$ to $M_{\overline{3}}$, but in H.sapiens only for $M_{\overline{1}}$ of the molars. The divergence between the roots (Fig. 54) of two-rooted premolars is very similar in the fossil hominid groups, being slightly greater in $P_{\overline{4}}$ than in $P_{\overline{3}}$. With a couple of exceptions, there is overall similarity between the groups in the divergence between the roots of each molar. However, the divergence between the $M_{\overline{1}}$ roots is much more marked in group A than in the other groups, resulting from marked distal angulation of the distal root yet more or less vertical orientation of the mesial root in this group. In group B, the $M_{\overline{3}}$ roots appear more divergent than in the other groups. The roots of $M_{\overline{2}}$ and $M_{\overline{3}}$ are parallel or slightly convergent in H.sapiens as distal root angulation is similar to mesial root angulation in these teeth. This pattern is not seen in any of the fossil hominid groups.

vii) Crown dimensions

With one exception, the values of the coefficient of variation for the crown dimensions do not suggest greater variability within each of the fossil hominid groups than in the comparative samples. Only in group C is this suggested - for the $M_{\overline{1}}$ crown buccolingual diameter, where the value of the coefficient of variation (11.6) reflects the range between KNM-ER 1801 (13.2) and O.H.51 (12.9) on the one hand and KNM-ER 3734 (10.6) on the other.

The mean values of crown mesiodistal diameter and crown buccolingual diameter in the fossil hominid groups are plotted out in Figs 55 and 56, respectively, and statistical summaries for the crown dimensions are given in Appendix M. In the fossil hominid groups, the picture presented by the crown dimensions is broadly similar for the two dimensions. For $P_{\overline{3}}$ to $M_{\overline{3}}$ and with one exception, both dimensions are larger in group B than in the other groups. Only the $P_{\overline{3}}$ crown mesiodistal diameter in group A (L.H.4=11.4) appears similar to group B ($\overline{X}$=11.1). In contrast, in fossil hominid groups A, C and D there is broad similarity in the two dimensions for the molars, particularly $M_{\overline{1}}$ and $M_{\overline{2}}$. These groups differ more in the premolar region. The premolar crown mesiodistal diameters appear larger in group A than in groups C and D, while the premolar crown buccolingual diameters appear larger in groups A and D than in group C. However, group C is represented only by KNM-ER 3734, in which the buccolingual diameters of $P_{\overline{3}}$ (8.0) and $P_{\overline{4}}$ (8.1) are similar to the mean values ($P_{\overline{3}}$=7.9, $P_{\overline{4}}$=8.3) recorded for the modern Homo sapiens sample. In contrast to the large size of the postcanine crown dimensions in group B, the crown dimensions of the anterior teeth are similar to those recorded for group D.

viii) Summary

Although this assessment of the dimensions and indices in the fossil hominid groups was intended to cover all the mandibular dentition, in practice some teeth are much better represented in some of the hominid groups than are others. The incisors and canine are very poorly represented in all

Fig. 55 : Mean values of crown mesiodistal diameter in the mandibular teeth of the fossil hominid groups

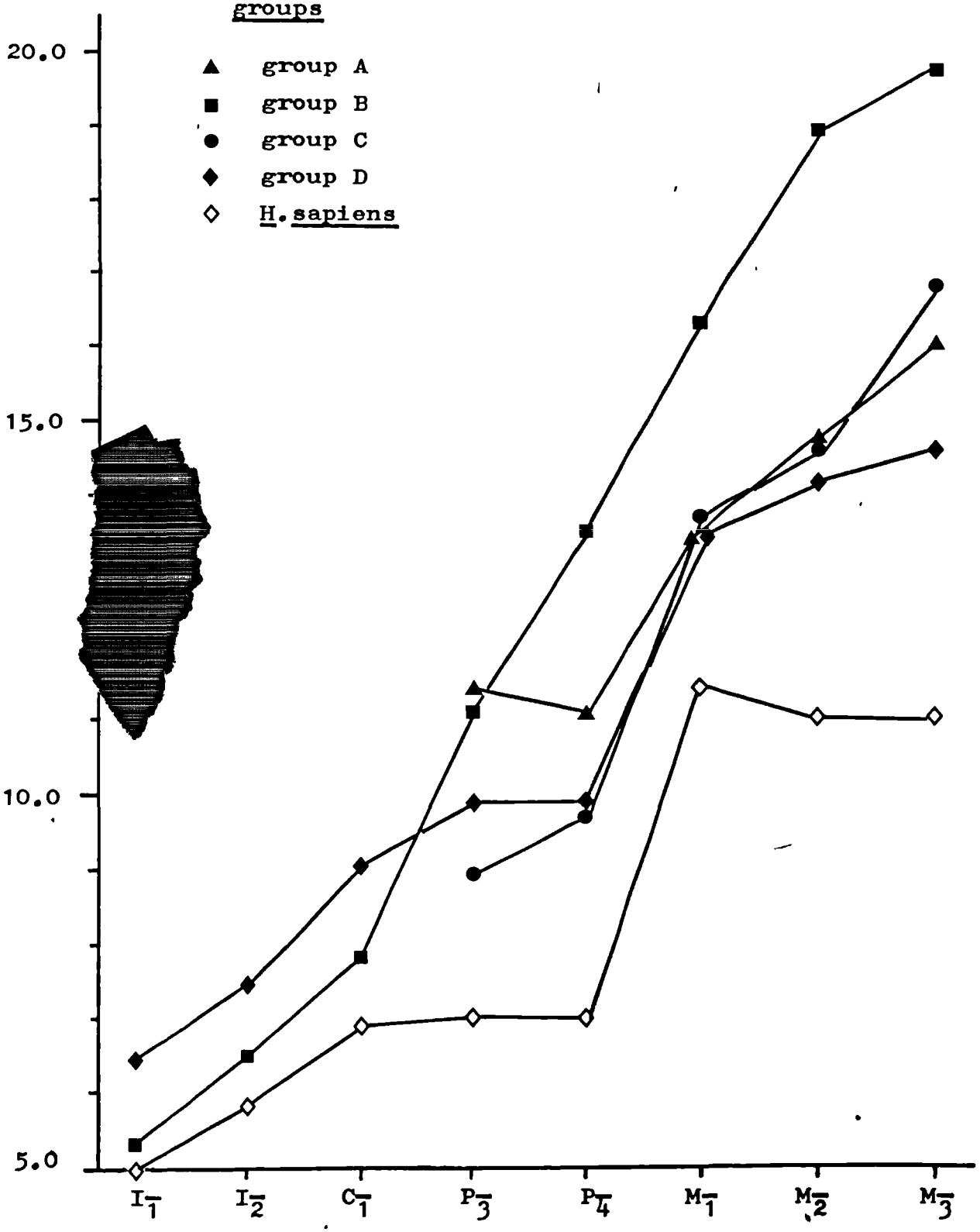
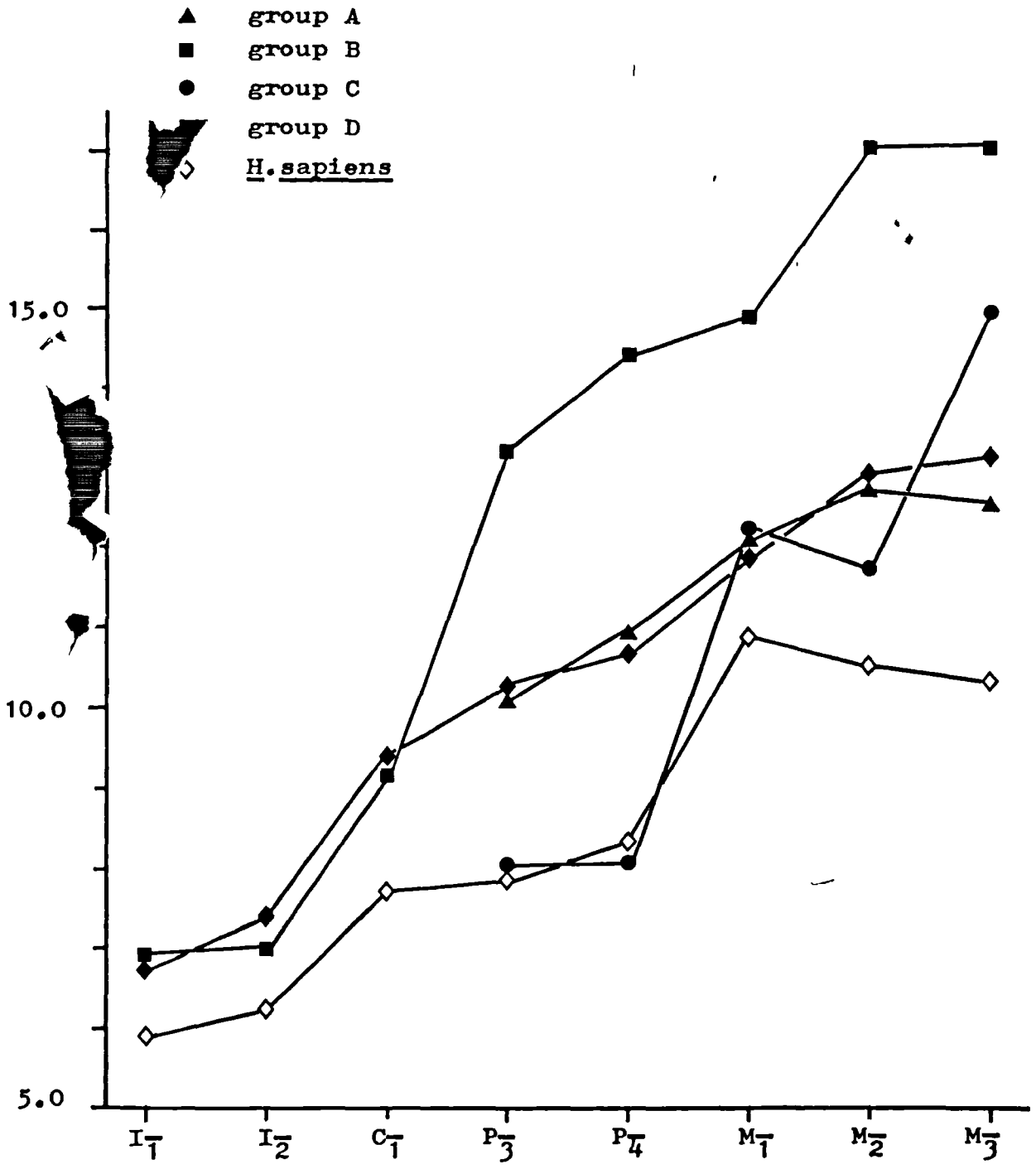


Fig. 56 : Mean values of crown buccolingual diameter in the mandibular teeth of the fossil hominid groups



groups, and so too is $P_{\overline{3}}$ in groups A and C. The former group is made up of seven specimens (KNM-ER 403, KNM-ER 725, KNM-ER 730, KNM-ER 733, KNM-ER 1805, KNM-ER 3729, L.H.4) and the latter contains only six (KNM-ER 819, KNM-ER 1482, KNM-ER 1801, KNM-ER 1811, KNM-ER 3734, O.H.51), but these sample sizes represent the maximum - for many dimensions, the sample size is less. In comparison, the teeth $P_{\overline{4}}$ to $M_{\overline{3}}$ are well represented in groups B and D, the former group cont[illegible] twelve specimens (KNM-ER 726, KNM-ER 729, KNM-ER 810, [illegible]-ER [illegible]18, KNM-ER 1468, KNM-ER 1802, KNM-ER 1806, KNM-ER 3229, [illegible]NM-ER 3230, KNM-ER 3731, KNM-ER 3954, Peninj) and the lat[illegible] thirteen (KNM-ER 992, KNM-ER 1483, KNM-ER 1501, KNM-ER 1812, KNM-ER 3889, L.H.10, L.H.14, O.H.7, O.H.13, O.H.16, O.H.22, O.H.23, O.H.37). During any assessment such as this, it is important to keep in mind the pitfalls of placing too much reliance on observations derived from small sample size.

The dimensions and indices were examined to see whether the coefficients of variation suggested heterogeneity within any of the fossil hominid groups or indicated possible sites of evolutionary change or divergence within the fossil hominid sample as a whole.

For many of the dimensions and indices, the values obtained for the coefficient of variation in group A are greater than those recorded in any of the comparative samples, indicating that it is highly unlikely that this group is taxonomically valid. However, the suggestion of greater variability applies particularly to the root dimensions and indices, whereas the

variation exhibited by the crown dimensions ($P_{\overline{4}}$ to $M_{\overline{3}}$) compares with that found in the comparative samples. In group A, greater variability than found in any comparative sample is indicated for the following root dimensions and indices: the neck mesiodistal diameters of $P_{\overline{4}}$ and $M_{\overline{3}}$ and, to a lesser degree, $M_{\overline{1}}$; the height of the $M_{\overline{1}}$ and $M_{\overline{2}}$ roots and, to a lesser degree, the $P_{\overline{4}}$ distal and $M_{\overline{3}}$ mesial roots; the root mesiodistal diameters of the distal roots of $P_{\overline{4}}$ and $M_{\overline{1}}$ and, to a lesser degree, the $P_{\overline{4}}$ mesial root; the robusticity of the mesial roots of $M_{\overline{1}}$ and $M_{\overline{2}}$ and, particularly, $M_{\overline{3}}$; the mandibular molar heights of bifurcation. Of these dimensions, neck mesiodistal diameter is small in KNM-ER 730 ($M_{\overline{1}}$ $M_{\overline{3}}$) and L.H.4 ($P_{\overline{4}}$) compared with the large size of KNM-ER 403 ($P_{\overline{4}}$ $M_{\overline{1}}$), KNM-ER 725 ($P_{\overline{4}}$ $M_{\overline{1}}$ $M_{\overline{3}}$) and KNM-ER 733 ($M_{\overline{1}}$ $M_{\overline{3}}$). However, the $M_{\overline{1}}$ and $M_{\overline{3}}$ neck mesiodistal diameters are of intermediate size in L.H.4. The roots are short in L.H.4 compared with KNM-ER 403 and KNM-ER 733, but especially in comparison to KNM-ER 730. In both L.H.4 ($P_{\overline{4}}$m $P_{\overline{4}}$d $M_{\overline{1}}$d) and KNM-ER 730 ($M_{\overline{1}}$d), the root mesiodistal diameters are small compared with KNM-ER 403 ($P_{\overline{4}}$m $P_{\overline{4}}$d $M_{\overline{1}}$d). The robusticity of the mandibular molar mesial roots is greatest in L.H.4, being intermediate in KNM-ER 403 and KNM-ER 733, and least in KNM-ER 730. The molar heights of bifurcation are small in L.H.4 compared with KNM-ER 403, KNM-ER 730 and KNM-ER 733.

In contrast to group A, few dimensions or indices appear sufficiently variable in group B to suggest that this is a heterogeneous group. In group B, the coefficients of variation for several dimensions and indices are close in value to the maximum recorded in any comparative sample, but only that for

the $P_{\overline{4}}$ location of bifurcation seems sufficiently larger to suggest greater variability in group B than in the comparative samples. The variability of this dimension in group B reflects the size difference between KNM-ER 3954 on the one hand and KNM-ER 729 and KNM-ER 3230 on the other. None of the other locations of bifurcation is suggestive of greater variability in group B than in the comparative samples, but KNM-ER 3954 contributes to the $P_{\overline{4}}$ sample only.

In fossil hominid group C, the height and robusticity of some roots and the $M_{\overline{1}}$ crown buccolingual diameter appear to be more variable than in any comparative sample. The high variability of the $M_{\overline{1}}$ root heights reflects the difference between the short roots of KNM-ER 1801 and the long roots of O.H.51, with KNM-ER 3734 having roots of intermediate height. To a lesser degree, $P_{\overline{3}}$ mesial root height is also more variable in group C, reflecting the difference in root height between KNM-ER 1482 and KNM-ER 3734 on the one hand and the short roots of KNM-ER 1801 on the other. The robusticity of the mesial roots of $P_{\overline{3}}$ and $P_{\overline{4}}$, but especially of the $P_{\overline{4}}$ distal root, also appear more variable in group C than in any comparative sample. For the $P_{\overline{4}}$ roots, this seems to reflect greater robusticity in KNM-ER 819 than in the other specimens, while for the $P_{\overline{3}}$ mesial root it reflects the difference between the greater robusticity of KNM-ER 1801, the intermediate robusticity of KNM-ER 1482 and the lesser robusticity of KNM-ER 3734. The higher value of the coefficient of variation for the $M_{\overline{1}}$ crown buccolingual diameter in group C than recorded in any comparative sample reflects the small size of KNM-ER 3734 compared with the larger size of KNM-ER 1801 and O.H.51.

Only the premolar root robusticities and the molar heights of bifurcation are suggestive of greater variability in fossil hominid group D than recorded for any comparative sample. For the $1PP_{\overline{4}}$ root, the difference between the greater robusticity of KNM-ER 1501 and O.H.37 at one extreme and the lesser robusticity of KNM-ER 992 and O.H.22 at the other underlies this high variability. The robusticity of the $1RP_{\overline{3}}$ root is also highly variable, but to a much lesser degree, here reflecting the difference between the greater robusticity of KNM-ER 1483 and the lesser robusticity of O.H.22. For each of the molar heights of bifurcation, the variation documented in group D is greater than in any comparative sample. Generally, this reflects the larger size of this dimension in specimens such as KNM-ER 992 and O.H.22 and its smaller size in specimens such as KNM-ER 1501, O.H.7, O.H.13 and O.H.16.

Thus, examination of the variability of the dimensions and indices in the fossil hominid groups suggests that group A, and possibly group C, may be heterogeneous, while there is little to support such a conclusion in the case of group B or group D.

Part IV : Discussion

Chapter 11 : Discussion and Conclusions

Part IV

Chapter 11 : Discussion and conclusions

i) Discussion

ii) Conclusions

Chapter 11 : Discussion and conclusions

The work of this thesis was initially prompted by the discovery at Koobi Fora, Kenya, of fossil hominid specimens in which some or all of the tooth crowns are missing. The absence of the tooth crowns, which for so long have been the mainstay of so many hominid studies, stimulated a closer examination of the tooth roots. Were there, for example, aspects of the size or form of the roots which would be taxonomically or phylogenetically useful in hominid studies? Any such features would obviously be singularly important for the assessment of fossil hominid specimens, such as KNM-ER 1468, KNM-ER 1501 or KNM-ER 1801, in which all tooth crowns are missing or damaged and in which most surface detail is obliterated through damage and erosion. In addition, any such aspects of tooth roots would play a role in the testing and modification of current hypotheses about hominid taxonomy and phylogeny.

The assessment of fossil hominid tooth roots requires a biological perspective, which is a knowledge of root morphology in the pongids and Homo sapiens. While a search of the published literature revealed little information on these aspects of the pongid dentition, though there exists a sizeable body of information on the modern human dentition, it did become clear that the form of premolar roots would almost certainly prove to be of particular interest in an assessment of fossil hominid tooth roots as these teeth had clearly been a focus of evolutionary change within the Hominoidea. Subsequent detailed examination of mandibular premolar root form in the hominid sample has confirmed this impression.

i) Discussion

Mandibular premolar root form

This radiographic study has indicated that, in each of the extant pongids, the mandibular premolars are typically two-rooted, the $P_{\overline{3}}$ having mesiobuccal and distal roots, and the $P_{\overline{4}}$ mesial and distal roots. This assessment of typical pongid mandibular premolar root form concurs with previous observations (James, 1960; Owen, 1840-45; Peyer, 1968; Scott & Symons, 1974; Tomes, 1923; Weidenreich, 1937). Similar mandibular premolar root form seems also to be typical of the hylobatid dentition (Duckworth, 1923; Peyer, 1968; Scott & Symons, 1974). Intra-specific variation was recorded for $P_{\overline{3}}$, but not for $P_{\overline{4}}$. Occasionally in Pongo (3%), and more frequently in Pan (29%), the $P_{\overline{3}}$ appeared, at least radiographically, to have a single root. Such a $P_{\overline{3}}$ root form was not observed in Gorilla. Variation in mandibular premolar root form has been recorded previously in pongids and hylobatids. In Pan mandibular premolars, the roots may be fused (James, 1960; Tomes, 1923) or rotated buccolingually (Gregory & Hellman, 1926), either of which could result in a radiographic appearance of single-rootedness, and in Gorilla, the general contour and postioning of the $P_{\overline{3}}$ roots may vary (Gregory & Hellman, 1926). In about one-half of the males (26/56) and about one-third of the females (12/40) of a local population of Hylobates lar, $P_{\overline{3}}$ was observed to have a third root (Frisch, 1963, 1973).

During the course of this study, scant information has come to light concerning mandibular premolar root form in fossil hominoids. However, it seems certain that both premolars have roots of typical pongid form - i.e. that both were two-rooted, $P_{\overline{4}}$ with mesial and distal roots, and $P_{\overline{3}}$ probably with

mesiobuccal and distal roots. Specifically, such root form has been described for mandibular premolars of Siwalik dryopithecine specimens (Gregory & Hellman, 1926) and Siwalik specimen B.M.(N.H.) M.15423 (Leakey, 1970), Sugrivapithecus salmonatus and the Candir mandible of Sugrivapithecus alpani (Tekkaya, 1974), the Rusinga specimen no.394 originally assigned to Kenyapithecus africanus (Leakey, 1968), and for Gigantopithecus (Woo, 1962). The assumption that two-rooted mandibular premolars were typical for fossil hominoids is reinforced by the occurrence of such a root form in the mandibular premolars of cercopithecid monkeys (Duckworth, 1923; James, 1960; Owen, 1840-45; Scott & Symons, 1974; Senyurek, 1953; Tomes, 1923). The identification of the mandibular premolar root form typical for fossil hominoids is of interest to this study in that it provides the primitive mandibular premolar root form for the Hominidae.

According to the results of this study, the primitive hominid mandibular premolar root form should be the following. Typically, $P_{\overline{3}}$ has mesiobuccal and distal roots, of which the mesiobuccal is obliquely aligned and contains a single pulp canal, and the distal is transversely orientated and contains two pulp canals. $P_{\overline{4}}$ has mesial and distal roots, which are not noticeably displaced in the buccolingual axis with respect to each other. Each of them is more or less transversely orientated and contains two pulp canals. In both $P_{\overline{3}}$ and $P_{\overline{4}}$, the level of bifurcation is high, being within the cervical third of root height, with the roots showing slight to moderate divergence in the mesiodistal plane. Of the specimens included in the fossil hominid sample used in this study, this root form is clearly present in both $P_{\overline{3}}$ and $P_{\overline{4}}$ of L.H.4 (the

holotype of Australopithecus afarensis (Johanson et al, 1978)), and in KNM-ER 403. It is also possibly present in KNM-ER 725, KNM-ER 733 and KNM-ER 3729. This assessment of root form concurs with that previously described for the $P_{\overline{3}}$ of L.H.4 (Johanson & White, 1979; White, 1977) and the $P_{\overline{4}}$ of KNM-ER 725 (Leakey et al, 1972), but seems in conflict with published descriptions of KNM-ER 403 (Leakey et al, 1971) and KNM-ER 733 (Leakey & Walker, 1973).

It is likely that this described root form is also present in hominids other than those included in this study sample. The mandibular premolar root form of Hadar hominids has been noted (Ward, 1979) to be reminiscent of pongids and Miocene hominoids. Specifically, the description of the $P_{\overline{3}}$ of A.L. 333w-60 (Johanson & White, 1979) indicates the presence of mesiobuccal and distal roots. The $P_{\overline{3}}$ root cross-section of MLD 29 is compatible, according to the observation of this author, with the presence of mesiobuccal and distal roots, and to judge from its initial description (Broom & Schepers, 1946) this root form is also suggested for the $P_{\overline{3}}$ of TM 1517. They describe the root as "somewhat ternate, suggesting that the root deeper in the jaw may divide into a smaller anterior root and possibly two posterior roots" (Broom & Schepers, 1946, p.102). In additon, this description of TM 1517 suggests bifurcation of the distal root, and in connection with this, two Hadar $P_{\overline{3}}$s have been described as three-rooted (Ward, 1979), as has the $P_{\overline{3}}$ of L.H.24 (White, 1980) which has mesiobuccal, distobuccal and distolingual roots. The $P_{\overline{3}}$s of KNM-ER 818 (Leakey & Walker, 1973) and KNM-ER 1803 (Day et al, 1976) have been each described as having a mesiobuccal root. In this study, neither $P_{\overline{3}}$ was assessed as having mesiobuccal and

distal roots, though it is possible in the case of KNM-ER 818.

As noted previously (chapter 9), the variety of mandibular premolar root form documented in the fossil hominid sample cannot all be explained by a scheme of root reduction from the mandibular premolar root form typical of primitive hominids to the single-rooted condition typical of both modern human mandibular premolars. In order to explain all variation encountered in the fossil hominid sample, it was proposed that, collateral with the trend toward root reduction, there has been a trend toward 'root molarisation' of mandibular premolar roots, culminating in the root form typical of the East African 'hyper-robust' australopithecines. When the trend toward root molarisation is fully realized, as in the specimens KNM-ER 729, KNM-ER 1468, KNM-ER 1806, KNM-ER 3229, KNM-ER 3230 and the Peninj mandible, the mandibular premolar roots exhibit the following features. The $P_{\overline{3}}$ and $P_{\overline{4}}$ are each supported by mesial and distal roots, which resemble those of mandibular molars. The distal root is displaced lingually with respect to the mesial root and is better developed lingually, where it provides support for the better-developed lingual side of the asymmetric premolar crown. The opposite applies in the case of the mesial root; its buccal portion is better developed than its lingual. These features are more accentuated in $P_{\overline{4}}$ than in $P_{\overline{3}}$. In both $P_{\overline{3}}$ and $P_{\overline{4}}$, the level of bifurcation is high, i.e., within the cervical third of root height. This assessment of root form in the above-mentioned specimens is compatible with published detail of mandibular premolar root form in KNM-ER 729 (Leakey et al, 1972) though the $P_{\overline{4}}$ roots are described as "mesial and buccal (sic?)", and for KNM-ER 1468 and KNM-ER 1806 (Day et al, 1976).

It is to be expected that, in some fossil hominids, features identified with root molarisation will not be as well developed as they are, for example, in KNM-ER 1806 or the Peninj mandible, as the mandibular premolar roots of such fossil hominids will be transitional in form between the primitiv premolar root form and the 'molarised' premolar root form. The morphological pathway from the former root form to the latter is suggested to be as follows. The $P_{\overline{3}}$ mesiobuccal root changes its orientation, to become more or less parallel to the distal root and more aptly described as mesial, and modifies its form to become mesiodistally compressed and possess two pulp canals. In each premolar (but especially in $P_{\overline{4}}$), the distal root changes its postion relative to the mesial root. From a postion more or less opposite the mesial root, the distal root becomes displaced lingually with respect to the mesial root, and the form of each root changes from more or less equal development of the buccal and lingual portions to greater development of the distal root lingually than buccally. The $P_{\overline{3}}$ root cross-section of KNM-ER 3731 may well be illustrative of such a stage in the change in the orientation and form of the mesiobuccal root. In this study, the root form of this $P_{\overline{3}}$ was classified as 2R:M+D as the root cross-section, though cervical to the level of bifurcation, most closely approximates the presence of mesial and distal roots. However, the oblique angulation of the buccal part of the mesial root is reminiscent of a mesiobuccal root, while the lingual portion of this root is small, anticipating rather than realizing the full development of this root part in the 'molarised' $P_{\overline{3}}$ root form.

Several other Koobi Fora hominids clearly lie along the continuum between the primitive and molarised premolar root

form, but their positions are uncertain. The $P_{\overline{4}}$s of these specimens have mesial and distal roots, but damage in the $P_{\overline{3}}$ region renders the assessment of $P_{\overline{3}}$ root form an educated guess. Nevertheless, it seems more likely that KNM-ER 725, KNM-ER 733 and KNM-ER 3729 have $P_{\overline{3}}$s with mesiobuccal and distal roots, while KNM-ER 726, KNM-ER 810A and KNM-ER 818 have $P_{\overline{3}}$s with mesial and distal roots, thus indicating the positions of these specimens along the continuum relative to KNM-ER 3731 (Fig. 44). The features of lingual displacement of the distal root with respect to the mesial root and of unequal development of the buccal versus the lingual portions of the roots are little developed in the $P_{\overline{4}}$ of KNM-ER 726, but appear slightly more developed in KNM-ER 810A. The published descriptions of root form for the $P_{\overline{4}}$s of KNM-ER 725 and KNM-ER 726 (Leakey et al, 1972), and for both premolars of KNM-ER 810A (Leakey & Walker, 1973), appear to be in agreement with the assessments made in this study, while, as noted previously, those for both premolars of KNM-ER 733 and the $P_{\overline{3}}$ of KNM-ER 818 (Leakey & Walker, 1973) appear to conflict.

In addition to the fossil hominid specimens examined in this study, it is clear from published description that other early fossil hominids have mandibular premolars which exhibit some tendency toward root molarisation. The Omo $P_{\overline{3}}$ L.18-33 from Member D (Coppens, 1970) appears, from the illustration provided, to have mesial and distal roots. Of the South African early fossil hominid samples, two-rooted mandibular premolars in which the roots are mesial and distal have been described for some $P_{\overline{3}}$s and $P_{\overline{4}}$s from Swartkrans (Robinson, 1956; Sperber, 1974). More specifically, lingual displacement of the distal root with respect to the mesial root has been described for

the P_4s SK 7, SK 88 and SK 876, and in addition, SK 88 is noted to be three-rooted (Sperber, 1974), suggesting bifurcation of either the mesial or distal root. However, features suggestive of the trend toward root molarisation are not only found in the Swartkrans sample. In the Sterkfontein P_4 TM 1523, the distal root is displaced lingually with respect to the mesial root (Sperber, 1974) and appears better developed linguall than buccally, while the converse applies for the mesial root (Robinson, 1956).

In summary, it is proposed that, within the fossil hominid sample used in this study, there is evidence of a trend toward mandibular premolar root 'molarisation'. This has involved change in P_3 root form from the ancestral pattern of mesiobuccal and distal roots to the derived condition of mesial and distal roots, and change in the disposition and development of the roots within each mandibular premolar. The trend culminates in the root form present in East African 'hyper-robust' specimens from Koobi Fora, Peninj and probably Omo, and is identifiable in the mandibular premolars of some Swartkrans and Sterkfontein specimens.

Within the sample used in this study, it is also proposed that there is evidence of the trend toward reduction of the mandibular premolar roots from the ancestral pattern of a P_3 with mesiobuccal and distal roots, and a P_4 with mesial and distal roots, to the single-rooted condition typical of both modern human premolars. It is suggested that this trend was collateral to the trend toward premolar root 'molarisation'. It is proposed that root reduction is effected by the processes of apical displacement of the level of bifurcation, and

modification of the contour of the primary apical foramen (itself perhaps reflecting change in crown shape). Both of these mechanisms, particularly the first, can be seen to be progressively at work in the transition of premolar root form from the ancestral to the derived condition. In the case of $P_{\overline{3}}$, root form becomes modified from mesiobuccal and distal roots through a stage, firstly, of mesiobuccal and distolingual roots, and, secondly, of Tomes' root form, to the single-rooted condition. The transition in $P_{\overline{3}}$ root form can be visualized in the following way. Firstly, the transition from mesiobuccal and distal roots to mesiobuccal and distolingual roots requires a change in the contour of the primary apical foramen and slight relocation of the inter-radicular processes during root development. For the transition from the mesiobuccal and distolingual root form to Tomes' root form, apical displacement of the bifurcation is of primary importance. This occurs preferentially distobuccally so that the mesiolingual root cleft typical of Tomes' root remains. Finally, modification of Tomes' root form to a simple single root requires, during root development, the gradual suppression of the mesiolingual inter-radicular process. In the case of $P_{\overline{4}}$, root reduction is effected primarily through progressive apical displacement of the bifurcation.

Two specimens included in the fossil hominid sample, KNM-ER 730, KNM-ER 1805, may provide evidence of the beginnings of the trend toward root reduction. In KNM-ER 730, a specimen considered to represent the genus Homo (Leakey, 1971; Day & Leakey, 1973), the $P_{\overline{3}}$ is clearly supported by mesiobuccal and distal roots. It is interesting to note, in passing, that the mesiobuccal root projects mesially sufficient for it to adopt a position buccal to the $C_{\overline{1}}$ root, thus, as noted by

Day and Leakey (1973), contributing to the 'squared off' appearance of the dental arcade, and that this seems to be the self-same feature as that described for Ramapithecus wickeri (Andrews & Tekkaya, 1976), and Rusinga specimens no.276 (Leakey, 1967) and no.394 (Leakey, 1968), once referred to Kenyapithecus africanus. However, the suggestion of root reduction is found, not in the $P_{\overline{3}}$ of KNM-ER 730, but in the $P_{\overline{4}}$. At the level at which the $P_{\overline{3}}$ roots are clearly bifurcated, the $P_{\overline{4}}$ root cross-section is unbifurcate suggesting that a tendency toward apical displacement of the bifurcation may be present in the $P_{\overline{4}}$ of this specimen. $P_{\overline{4}}$ root form could not be assessed for KNM-ER 1805, but though damaged and eroded, the curved C-shaped $P_{\overline{3}}$ root cross-sections, which are exposed cervical to the level of bifurcation, are suggestive of some modification of the contour of the primary apical foramen in comparison to the $P_{\overline{3}}$ with typical mesiobuccal and distal roots. At a level apical to the bifurcation, these $P_{\overline{3}}$ root cross-sections appear compatible with the presence of, either closely-approximated mesiobuccal and distal roots, or perhaps more likely, mesiobuccal and distolingual roots.

The $P_{\overline{3}}$ root form of mesiobuccal and distolingual roots is present in some of the Koobi Fora specimens included in this study sample. Although as exposed, the $P_{\overline{3}}$ root cross-sections of KNM-ER 819, KNM-ER 1482, KNM-ER 1801 and KNM-ER 3734 are unbifurcate, radiography indicates the presence of two roots and these must be mesiobuccal and distolingual to be compatible with the contour of the root cross-section and the apparent locations of the pulp canals. Radiography also indicates the presence of mesial and distal roots for the $P_{\overline{4}}$ of each specimen. In KNM-ER 819, KNM-ER 1482 and KNM-ER 1801, the level of

bifurcation between the roots of each premolar appears high, i.e. within the cervical third of root height, while in the premolars of KNM-ER 3734 the bifurcation is displaced apically to a level corresponding to about half the root height, suggesting that root reduction has progressed further in this specimen than in the others.

It is evident that fossil hominids other than those included in this study sample have mesiobuccal and distolingual roots supporting the $P_{\overline{3}}$. Specifically, this root form is documented for the Kromdraai $P_{\overline{3}}$ TM 1600 (Sperber, 1974), and for the Sterkfontein $P_{\overline{3}}$ Sts 7 and probably for Sts 51 (Robinson, 1956). Some Hadar $P_{\overline{3}}$s may have mesiobuccal and distolingual roots, though this is not certain from the published description (Ward et al, 1982). However, it is clear that some Hadar $P_{\overline{3}}$s exhibit the tendency toward apical displacement of the bifurcatio as clear reference is made to root 'fusion' occurring within the cervical half of root height (Ward et al, 1982).

Developmentally, the transition from mesiobuccal and distolingual roots to Tomes' root form requires suppression of the distobuccal inter-radicular process, so that there is continuity distobuccally between the mesiobuccal and distolingual roots, yet normal development of the mesiolingual inter-radicular process, so that the mesiolingual cleft remains. Several specimens included in the fossil hominid sample have $P_{\overline{3}}$s which appear to show this transition. The $P_{\overline{3}}$ root cross-sections of KNM-ER 1811, KNM-ER 1812, KNM-ER 3889 and L.H.10 show a mesiolingual cleft penetrating into the root, but continuity between the roots distobuccally. The relative positions of these specimens along the trend to Tomes' root is uncertain

as the possibility of root bifurcation apical to the cross-section could not be assessed radiographically. At a level corresponding to these $P_{\overline{3}}$ root cross-sections, the $P_{\overline{4}}$ root cross-section of KNM-ER 1811 shows bifurcation into mesial and distal roots, while those of KNM-ER 3889 and L.H.10 are unbifurcate. This assessment of mandibular premolar root form is not incompatible with published description for KNM-ER 1811 and KNM-ER 1812 (Day et al, 1976), though it may be so for L.H.10 (White, 1977). In the $P_{\overline{3}}$ SK 72, the distobuccal level of bifurcation is displaced apically for a short distance (Robinson, 1956).

The displacement of the distobuccal level of bifurcation into the periapical region, combined with the presence of the mesiolingual cleft, is the equivalent of Tomes' root form. Of the specimens included in this study sample, this $P_{\overline{3}}$ root form appears to be present in fossil hominids from Koobi Fora, Laetoli and Olduvai Gorge. The isolated $P_{\overline{3}}$s of L.H.14 and O.H.16 clearly have roots of the Tomes' type which preserve distinct mesiobuccal and distolingual apices, and radiographical the presence of Tomes' root can be diagnosed for the $P_{\overline{3}}$s of KNM-ER 1483, KNM-ER 1501, O.H.13 and O.H.23. Accompanying the root reduction of $P_{\overline{3}}$, there is marked apical displacement of the bifurcation in $P_{\overline{4}}$. In the $P_{\overline{4}}$s of KNM-ER 1483, KNM-ER 1501 and O.H.23, and also in the $P_{\overline{4}}$ of O.H.37, the bifurcation appears radiographically to be displaced into the apical quarter of root height. The radiographic appearance of these $P_{\overline{4}}$ roots is compatible with the observed morphology of an isolated $P_{\overline{4}}$ of O.H.16, and the described morphology of the Omo $P_{\overline{4}}$ L751-1255 (Coppens, 1973b), in suggesting that, as in $P_{\overline{3}}$, the bifurcation may show greater apical displacement in one

region of the root than in another. In these isolated $P_{\overline{4}}$s, the bifurcation shows greater apical displacement buccally so that a cleft is apparent from the lingual aspect of the root.

In common with the specimens just described, Tomes' root is found in the $P_{\overline{3}}$s of other fossil hominids and probably occurs in the Hadar specimen A.L.288-1 (Johanson et al, 1982) and possibly in other Hadar specimens (Ward et al, 1982); in $P_{\overline{3}}$s from Sterkfontein and from Swartkrans, including SK 30 (Robinson, 1956); probably in the Kedung Brubrus mandible and in the isolated Trinil $P_{\overline{3}}$(Dubois,1924); in Sangiran 8 (Jacob, 1973; Von Koenigswald, 1968, 1969; Weidenreich, 1945); and in $P_{\overline{3}}$s of Atlanthropus (Arambourg & Hoffstetter, 1963) and Sinanthropus (Weidenreich, 1937). $P_{\overline{3}}$s from the neanderthal site of Krapina (Kallay, 1963) also show Tomes' root form. In most of these specimens, accompanying the presence of Tomes' root in $P_{\overline{3}}$, there is evidence of apical displacement of the bifurcation between the mesial and distal roots of $P_{\overline{4}}$.

The mandibular premolars of some specimens included in the fossil hominid sample appear on radiographs to be single-rooted, i.e. the radiographic image gives no indication of apical bifurcation, nor of marked clefts along the root surface. Radiographically, the $P_{\overline{4}}$s of KNM-ER 992 and O.H.13, and both premolars of O.H.22 are of this appearance. However, the description of O.H.22 (Rightmire, 1980) does suggest the presence of Tomes' root in the $P_{\overline{3}}$. In KNM-ER 992, root reduction appears to have progressed further in $P_{\overline{4}}$ than in $P_{\overline{3}}$. While the $P_{\overline{4}}$ root appears radiographically to be single, the $P_{\overline{3}}$ root is bifurcate for about half the root height.

Single-rooted premolars have been described for other fossil hominids: for the $P_{\overline{3}}$ SK 18A from Swartkrans (Broom & Robinson, 1952; Sperber, 1974), for both premolars of the Pithecanthropus modjokertensis mandible from Sangiran (mandible B Sangiran 1B)(Von Koenigswald, 1968), for the $P_{\overline{3}}$ of the Sidi Abderrahman mandible (Arambourg & Biberson, 1956), and for some Sinanthropus premolars (Weidenreich, 1937). The isolated $P_{\overline{4}}$ from Changyang is single-rooted, though the apex is marked by a short cleft (Chia, 1957).

The simple, single, conical premolar root, unmarked by root clefts, which is typical of modern Homo sapiens, represents the culmination of the trend toward premolar root reduction. However, it is clear that though this is the typical mandibular premolar root form for modern man, it does not necessarily occur with a frequency of 100% in modern human populations.

The scheme proposed here involving collateral trends of premolar root reduction and premolar root molarisation is not the first to be devised with the purpose of explaining mandibular premolar root form in the fossil hominids. Robinson (1952) put forward a scheme, in part hypothetical, suggesting the pathway of root reduction from double-rooted to single-rooted $P_{\overline{3}}$s. Robinson's scheme corresponds largely with that suggested here for the stages of $P_{\overline{3}}$ root reduction from mesiobuccal and distolingual roots to the single-rooted condition, but did not recognize, as suggested here, the ancestral hominid premolar root pattern of a $P_{\overline{3}}$ with with mesiobuccal and distal roots and a $P_{\overline{4}}$ with mesial and distal roots, nor did Robinson suggest that parallel to the trend to premolar root reduction there

has been a second trend in premolar root morphology, but towards 'root molarisation'.

Maxillary premolar root form

In this study, maxillary premolar root form was not assessed for the fossil hominid sample. This was in part due to the poor representation of the maxillary dentition in the site samples from which the fossil hominid sample was drawn, and also because the quality of most of the hominid maxillary cheek-tooth radiographs was poor, showing little detail. However, a certain amount of information on fossil hominid maxillary premolar root form has been published, and can be integrated with the scheme for mandibular premolar root form proposed here.

As indicated by observations made on extant pongids in this study, with one exception the maxillary premolars of the extant pongids are typically three-rooted, having mesiobuccal, distobuccal and lingual roots similar to those of maxillary molars. This observation is in broad agreement with published opinion that the pongid maxillary premolars are three-rooted (Colyer, 1936; Duckworth, 1923; James, 1960; Owen, 1840-45; Scott & Symons, 1974; Tomes, 1923). It seems also that three-rooted maxillary premolars are typical of the hylobatid and cercopithecid dentitions (Colyer, 1936; Duckworth, 1923; James, 1960; Owen, 1840-45; Peyer, 1968; Scott & Symons, 1974; Tomes, 1923). Thus, the evidence from comparative anatomy points to the three-rooted maxillary premolar as the ancestral pattern for the Hominidae. Evidence from fossil hominoids supports this conclusion; three-rooted maxillary premolars have been

described for Rusinga specimen CMH6, the Songhor specimen no.52/111 and the Songhor specimen no.748 (Leakey, 1967), for the Nagri specimen D.185 (Prasad, 1969), and for Gigantopithecus (Woo, 1962).

Just as variation is encountered in mandibular premolar root form in the early fossil hominids, so is it in maxillary premolar root form. The form suggested here to be the ancestral hominid root pattern - the three-rooted maxillary premolar - is found in hominids. Such a root system has been claimed for specimens attributed to Australopithecus afarensis (Johanson et al, 1978; Johanson & White, 1979) though no specific reference to this root form is to be found in the detailed descriptions of the Hadar and Laetoli material (Ward et al, 1982; White, 1977, 1980). Three-rooted maxillary premolars have also been described for the Sterkfontein P^3, Sts 54 (Robinson, 1956), for the Kromdraai specimens TM 1517 and the fragmentary right maxilla (Broom & Schepers, 1946; Robinson, 1956), and in most, but not all, of the Swartkrans maxillary premolars (Robinson, 1956). The three-rooted maxillary premolar is also encountered in fossil hominid specimens generally taken to represent the East African 'hyper-robust' form of australopithecine, i.e. O.H.5 (Tobias, 1967) and KNM-ER 405 and KNM-ER 406 (Leakey et al, 1971), KNM-ER 732 (Leakey et al, 1972) and KNM-ER 733 (Leakey & Walker, 1973). In all these specimens, the ancestral root form is maintained, and, because it is the root form typical of maxillary molars, it could be suggested that this corresponds to the trend of 'root molarisatio proposed for the mandibular premolars. In connection with this, it is interesting to note the occurrence of 'fusion' between the mesiobuccal and lingual roots of some Swartkrans

maxillary premolars, for example the P^3 SK 24 and the P^4s SK 28 and SK 32 (Broom & Robinson, 1952; Robinson, 1956; Sperber, 1974); root fusion of this type is well documented in modern human maxillary molars. In the light of these suggestions, the documented occurrence of three-rooted maxillary premolars in the Sterkfontein specimen Stw 53 which has been referred to the genus Homo (Hughes & Tobias, 1977); in SK 80, the Telanthropus maxilla (Robinson, 1953); and in Pithecanthropus IV (Von Koenigswald, 1969) is of great interest.

In other fossil hominids, there is a clear trend toward root reduction in the maxillary premolars, just as has already been described for mandibular premolars. This trend involves the transition from a three-rooted to a single-rooted premolar and is suggested to be effected in the following manner. The transition from the three-rooted to the two-rooted form involves progressive apical displacement of the bifurcation between the two buccal roots and also, reflecting the progressive suppression of the involved inter-radicular processes during root development, the progressive weakening of the longitudinal root grooves marking the buccal and lingual surfaces of the now-single buccal root. The transition from the two-rooted to the single-rooted premolar involves the same factors working between the buccal and lingual roots. This transition is not yet complete - in modern man, apical bifurcation is encountered in maxillary premolars, particularly in P^3 where more pronounced bifurcation is not uncommon in some populations.

Some Swartkrans premolars, such as the P^3 SK 74c and the P^4s SK 39 and SK 11, appear to be examples of the transition from the three-rooted to the two-rooted premolar as the level

of bifurcation between the buccal roots is displaced apically (Robinson, 1956; Sperber, 1974). In the Laetoli P_4 L.H.22 (White, 1980) the level of bifurcation between the buccal roots is displaced to close to the apex. The P^3 L.H.25 (White, 1980) is effectively two-rooted - the buccal root showing only the slightest signs of apical bifurcation. Two-rooted maxillary premolars are found in a range of hominids : L.H.5 (White, 1977) and Hadar specimens (Ward et al, 1982); Makapansgat and Sterkfontein specimens (Robinson, 1956; Sperber, 1974) including TM 1511 (Broom, 1936); some Swartkrans specimens such as the P_4 SK 881 (Robinson, 1956; Sperber, 1974); the Koobi Fora specimens KNM-ER 1470 (Day et al, 1975) and KNM-ER 1813 (Day et al, 1976); the Omo cranium L.894-1 referred to the genus Homo (Boaz & Howell, 1977); Sangiran 15 (Jacob, 1972) and the Sinanthropus P^3 no.19 (Weidenreich, 1937). The maxillary premolars from the neanderthal site of Krapina are also usually two-rooted (Kallay, 1963).

Maxillary premolar root reduction has progressed further in some other fossil hominids. In the Rabat maxillary fragment, the P_4 is single-rooted, though the P^3 is double-rooted (Howell, 1960). Most Sinanthropus maxillary premolars are single-rooted, though apical bifurcation occurs in some (Weidenreich, 1937; Woo & Chia, 1954), and, finally, the Sterkfontein P^3 - Sts 47 - has a single root (Robinson, 1956; Sperber, 1974).

Premolar root form - its application in hominid studies

As far as the fossil hominid sample is concerned, this thesis has concentrated on aspects of mandibular premolar root form rather than on maxillary premolar root form. A

scheme involving root reduction on the one hand and root molarisation on the other has been proposed to explain the observed variation of hominid mandibular premolar root form, and it is suggested that similar trends can be traced in fossil hominid maxillary premolar root form. It is proposed that this scheme has phylogenetic implications, but whether features of mandibular premolar root form, or, for that matter, of maxillary premolar root form, should be used for taxonomic purposes is another question, and one which would require further study, particularly into aspects of intra-specific variation in premolar root form. A point worth making, however, is that as mandibular premolar root form in the 'hyper-robust' australopithecines represents a derived condition with respect to the primitive pattern for the Hominidae, while maxillary premolar root form corresponds to the primitive pattern, the root form of the mandibular premolars should prove of more use in certain contexts for the assessment of the phylogenetic position of hominid specimens.

The proposed scheme of mandibular premolar root form argues against the inclusion in the same lineage of fossil hominid specimens which exhibit features associated with root reduction with fossil hominid specimens which exhibit features of root molarisation. In many instances, such confusion would not anyway arise - other anatomical features clearly indicating the evolutionary separation between such specimens. However, it seems that mandibular premolar root form may have a part to play in some circumstances. For example, the assessment of mandibular premolar root form made in this study for KNM-ER 1802 argues against its inclusion in a group with specimens such as KNM-ER 1470 and KNM-ER 1482, as suggested by Leakey

(1980), but instead suggests that it should be included in the clade or lineage leading to the 'hyper-robust' australopithecines. Also, fresh assessment of the Sterkfontein and Swartkrans hominid samples should prove interesting as, at each site, there appears to be a mixture of specimens, some showing features of mandibular premolar root reduction, some of mandibular premolar root molarisation. Lastly, the proposed scheme of mandibular premolar root form may provide, on closer inspection of the relevent specimens, further insight into the phyletic positions (Johanson, 1980; Tobias, 1980; White et al, 1981) of Australopithecus afarensis and A.africanus

The root dimensions in the comparative samples

As far as this author is aware, published documentation and assessment of root dimensions is very limited in the case of Homo sapiens and seemingly non-existant in the case of the pongids. For this reason, one of the aims of this thesis has been the documentation of the root dimensions in the comparative samples, with the particular purpose of providing a comparative basis for the examination of the root dimensions in the fossil hominid sample. In addition, a concomitant of the dearth of published information on root size in the comparative samples is that there is little with which to compare the results of the present study.

The variability of the dimensions has already been examined (chapter 6), and has indicated that in all the comparative samples the root dimensions are more variable than the crown dimensions, some of them slightly so, but others, such as height of bifurcation, much more so. Generally, and with the notable exception of $C_{\overline{1}}$ dimensions in the pongids ($C_{\overline{1}}^{1}$ not

measured), high variability of dimensions does not necessarily reflect the presence of sexual dimorphism. In many instances, there is no evidence of sexual dimorphism for dimensions which are highly variable in the pooled-sex comparative samples, and conversely, dimensions which are sexually dimorphic are not necessarily more variable than those which are not. However, for $C_{\overline{1}}$ dimensions in the pongids there appears to be a relationship between high variability and the presence of sexual dimorphism. These observations support the distinction between sexually overlapping and sexually non-overlapping variates which was proposed by Pilbeam and Zwell (1972).

These observations may have implications for the study of relationships between dimensions using correlation analysis. The preliminary assessment of relationship between root height and other dimensions in this study followed the pattern and technique of previous work on the relationship between root height and facial proportions (Riesenfeld, 1970; Riesenfeld & Siegel, 1970; Siegel, 1971; Siegel, 1972). However, it has been suggested (Siegel, 1978) that the lumping of males and females for correlation analysis which involves sexually dimorphic dimensions which are bimodal in distribution, such as pongid $C_{\overline{1}}$ dimensions, may lead to spurious results. This should be taken into account in any further work which seeks to investigate the relationship between root dimensions and other dental and gnathic variables.

Of the comparative samples, sexual dimorphism is most apparent in the root dimensions of Gorilla and Pongo, being much less evident in Pan and Homo sapiens. However, all the pongids agree in being sexually dimorphic for the $C_{\overline{1}}$ root

dimensions, and usually to a pronounced degree. Otherwise, Gorilla is sexually dimorphic particularly for the anterior dentition extending into P3; marked sexual dimorphism is exhibited by most incisor root dimensions and by very nearly all $P_{\overline{3}}$ root dimensions, though in $P^{\underline{3}}$ sexual dimorphism is marked only for the root height of the mesiobuccal root. In contrast to the $P_{\overline{3}}$ of Gorilla, and of Pongo as this tooth also exhibits marked sexual dimorphism in most of its root dimensions, the $P_{\overline{3}}$ of Pan is not sexually dimorphic - neither in its root dimensions, nor in its crown dimensions. In addition to the extensive and marked expression of sexual dimorphism in the root dimensions of the Pongo $C_{\overline{1}}$ and $P_{\overline{3}}$, marked sexual dimorphism seems to be expressed particularly in the root heights of the mandibular dentition and also of $M^{\underline{3}}$. Few root dimensions of the Homo sapiens dentition are sexually dimorphic, but those that are tend to be localised in the region of the first and second molars, though the most marked sexual dimorphism is found in $C_{\overline{1}}$ root height. This pattern is unlike that described for the Norwegian Lapps (Selmer-Olsen, 1949) in whom sexual dimorphism was more marked in the root heights of the anterior dentition than in those of the molars. In the present study, sexual dimorphism was recorded for the root heights of the $C_{\overline{1}}$, $P_{\overline{4}}$, $M_{\overline{1}}$ and $M_{\overline{2}}$, in contrast to its absence in the correspondi crown dimensions with the exception of the $P_{\overline{4}}$ buccolingual diameter. These results largely concur with those of Garn et al (1978b) who noted a greater degree of sexual difference in root height than in crown dimensions for the $C_{\overline{1}}$ to $M_{\overline{2}}$.

11) Conclusions

The potential of tooth root morphology as a source of information for hominid studies has, with few exceptions, long remained unexplored. The work presented in this thesis redresses the balance slightly, but still represents only an initial foray into the subject of root size and form in the fossil hominids. However, the indications are that tooth root morphology can contribute to a better understanding of evolution within the Hominidae. From the broad subject tackled in this thesis, premolar root form - particularly of the mandibular teeth - has emerged as an indicator of evolutionary change within the early fossil hominids. On the one hand, a trend toward 'root molarisation' has been identified which culminates in the mandibular premolar root form found in the hyper-robust australopithecines; on the other hand, a collateral trend of root reduction can be traced from the ancestral hominid mandibular premolar root pattern to that typical of modern Homo sapiens. Refinement and modification of the details of the proposed scheme would no doubt ensue from examination of premolar root form in a sample which embraced as many of the early fossil hominids as possible.

The fossil hominid specimens examined in this study were grouped according to their mandibular premolar root form. Some of these groupings were supported by examination of the root dimensions, some not. When the variability of the root and crown dimensions in the comparative samples is used as a guideline, the variability of the corresponding dimensions in the fossil hominid group which included hyper-robust australopithecine specimens, such as KNM-ER 729 and KNM-ER

1806, in addition to other specimens such as KNM-ER 810A, KNM-ER 1802 and KNM-ER 3954, and in the group which included Homo habilis specimens in addition to some Laetoli specimens and Koobi Fora specimens such as KNM-ER 1501 and KNM-ER 992, does not suggest heterogeneity in either group.

The purpose behind documenting the root dimensions in the comparative samples was very much to provide a comparative guideline which would be useful for this and other studies of hominid root size. To this end, the aspects of the root dimensions which were concentrated on were variability, and also its possible relationship with the presence of sexual dimorphism. With the notable exception of $C_{\overline{1}}$ dimensions in the pongids, high variability in root dimensions bears no clear relationship to the presence of sexual dimorphism. There is obviously great scope for research into other aspects of root size in comparative samples such as the ones used in this study. For example, an area of interest would be the relationship between crown size and root size.

Information published on root development and its relationship with root morphology has provided the mechanisms through which change in root form can be effected, thus indicating the probable ways in which premolar 'root molarisation' on the one hand and premolar root reduction on the other have taken place. An off-shoot of familiarity with these processes is support for the suggestion that taurodontism, rather than being some enigmatic trait of uncertain significance, represents the process of root reduction at work in molars.

Part V : References

References

Abrahams,L.C. (1946-47) The masticatory apparatus of the people of Calvinia and Namaqualand in the North Western Cape of the Union of South Africa. J. dent. Ass. S. Afr. 1(4): 5-51

Ackerman,J.L., Ackerman,A.L. and Ackerman,A.B. (1973) Taurodont, pyramidal and fused molar roots associated with other anomalies in a kindred. Am. J. phys. Anthrop. 38: 681-694.

Addison,W.H.F. and Appleton,J.L.T. (1928) Root development, and the light it throws on certain peculiarities of the roots and root-canals. J. dent. Res. 8: 403-404.

Adloff,P. (1908) Das Gebiss des Menschen und der Anthropomorphen. Berlin (cited by Keith, 1913).

Adloff,P. (1914-15) Probleme der Gebissentwickelung. Ztschr. f. Morphol. u. Anthropol. 17: 433-448 (cited by Pedersen, 1949).

Aeby,C. (1878) Die Architektur unvollkommen geteilter Zahnwurzeln. Arch. mikr. Anat. 15: 360-371 (cited by Butler, 1956).

Alexandersen,V. (1962a) Rodforholdene hos menneskets underkaebehjornetaender med saerligt henblik pa torodede hjornetaender. I. Den morfologiske variation. Tandlaegebladet 66: 53-80.

Alexandersen,V. (1962b) Rodforholdene hos menneskets underkaebehjornetaender med saerligt henblik pa torodede hjornetaender. II. Forekomst af torodede hjornetaender i underkoeben hos Homo sapiens og hos andre primater. Tandlaegebladet 66(12): 729-760.

Alexandersen,V. (1963) Double-rooted human lower canine teeth. In Dental Anthropology. (ed) D. Brothwell pp. 235-244.

Ando,S., Kiyokamwa,K., Nakashima,T., Shinbo,K., Sanka,Y., Oshima,S. and Aizawa,K. (1967) Studies on the consecutive survey of succedaneous and permanent dentition in the Japanese children. Part 4. Behaviour of short-rooted teeth in the upper bilateral central incisors. J. Nihon Univ. Sch. Dentistry 9: 67-82.

Andrews,P. and Tekkaya,I. (1976) Ramapithecus in Kenya and Turkey. U.I.S.P.P. Colloque VI: 7-25.

Arambourg,C. and Biberson,P. (1956) The fossil human remains from the Palaeolithic site of Sidi Abderrahman (Morocco). Am. J. phys. Anthrop. 14: 467-489.

Arambourg,C. and Hoffstetter,R. (1963) Le gisement de Ternifine. Arch. Inst. Paleont. hum. Memoire 32.

Armitage,B. (1971) Three-rooted first premolars and their genetic and anthropological significance. Br. dent. J. 130: 245-246.

Badger,G.R. (1982) Three-rooted mandibular first primary molar. Oral Surg. 53(5): 547.

Barker,B.C.W. (1964) A two-rooted permanent maxillary median incisor. Aust. dent. J. 9: 501.

Barker,B.C.W. (1973) Dental anthropology: some variations and anomalies in human tooth form. Aust. dent. J. 18: 132-140.

Barker,B.C.W., Parsons,K.C., Mills,P.R. and Williams,G.L. (1973) Anatomy of root canals. I. Permanent incisors, canines and premolars. Aust. dent. J. 18: 320-327.

Barker,B.C.W., Parsons,K.C., Mills,P.R. and Williams,G.L. (1974) Anatomy of root canals. III. Permanent mandibular molars. Aust. dent. J. 19: 408-413.

Barker,B.C.W., Parsons,K.C., Mills,P.R. and Williams,G.L. (1975) Anatomy of root canals. IV. Deciduous teeth. Aust. dent. J. 20: 101-106.

Barnes,D.S. (1969) Tooth morphology and other aspects of the Teso dentition. Am. J. phys. Anthrop. 30: 183-193.

Barr,J.H. and Gron,P. (1959) Palate contour as a limiting factor in intraoral x-ray technique. Oral Surg. 12: 459-472.

Benkow,H.H. (1957) A new principle and appliance for radiographic tooth measurements. J. dent. Res. 36(4): 641-643.

Bernick,S. and Levy,B.M. (1968) Studies on the biology of the periodontium in Marmosets: I. development of bifurcation in multirooted teeth in marmosets (Callithrix jacchus). J. dent. Res 47(1):

Best,E.J., Gervasio,W., Sowle,J.T., Winter,S. and Gurney,B.F. (1960) A new method of tooth length determination for endodontic practice. Dent. Dig. 66(10): 450-454.

Bhaskar,S.N. (1980) Orban's oral histology and embryology.

Bimstein,E. and Bystrom,E.B. (1982) Bi-rooted bilateral maxillary primary canines. J. Dent. Child 49(3): 217-218.

Birnbaum,A.S. (1936) First molar with three roots. Dental Cosmos 78: 657.

Black,D. (1927) On a lower molar hominid tooth from the Chou Kou Tien deposit. Palaeont. Sin. ser D, vol 7, fasc 1.

Black,G.V. (1902) Descriptive anatomy of the human teeth. S.S. White Dent. Man. Co., Philadelphia.

Bloch,M. (1936) Dental anomalies. Dental Cosmos 78: 657.

Blumberg,J.E., Hylander,W.L. and Goepp,R.A. (1967) A biometric delineation of taurodontism in a modern population. Am. J. phys. Anthrop. 27: 239.

Blumberg,J.E., Hylander,W.L. and Goepp,R.A. (1971) Taurodontism: A biometric study. Am. J. phys. Anthrop. 34: 243-255.

Boaz,N.T., and Howell,F.C. (1977) A gracile hominid cranium from Upper Member G of the Shungura Formation, Ethiopia. Am. J. phys. Anthrop. 46(1): 93-108.

Bolk,L. (1915a) Bemukungen uber Wurzelvariationen am menschlichen unteren Molaren. Ztschr. f. Morphol. u. Anthropol. 17: 605-610.

Bolk,L. (1915b) Das Carabellische Hockerchen. Schw. Vierteljahrsschrift f. Zahn 25: 1-24 (cited by Jorgensen, 1956).

Brabant,H. (1963) Observations anthropologiques et odontologiques sur les dents des Hutu, du Rwanda. Musee Royal de l'Afrique Centrale, Annales, Serie in 8°, Sciences Humaines, no 47.

Brabant,H. (1965) Contribution odontologique a l'etude des ossements trouves dans la necropole protohistorique de Sanga, republique du Congo. Musee Royal de l'Afrique Centrale, Annales, Serie in 8°, Sciences Humaines, no 54.

Brabant,H. (1969) Observations sur les dents des populations megalithiques d'Europe occidentale. Bull. Gp. int. Rech. Sc. Stomat. 12: 429-460.

Brabant,H. (1971) Some facts on the human dentition during the Megalithic era. In Dental Morphology and Evolution (ed) A.A. Dahlberg pp. 283-298.

Brabant,H., Klees,L. and Philippart,R. (1953) Contribution clinique et histologique a l'etude des dents et des racines surnumeraires. Arch. Stomat. Liege 8: 1-24.

Brabant,H. and Kovacs,I. (1961) Contribution a l'etude de la persistence du taurodontisme dans les races modernes et du sa parente possible avec la racine pyramidale des molaires. Bull. Gp. int. Rech. Sc. Stomat. 4(2 & 3):

Brabant,H. and Kovacs,I. (1964) Contribution a l'etude du taurodontisme des molaires temporaires. Bull. Gp. int. Rech. Sc. Stomat. 7: 372-400.

Brabant,H., Sahly,A. and Bouyssou,M. (1961) Etude des dents prehistoriques de la station archeologique des Matelles, department de l'Herault, France. Bull. Gp. int. Rech. Sc. Stomat. 4: 382-448.

Bramante,C.M. and Berbert.A. (1974) A critical evaluation of some methods of determining tooth length. Oral Surg. 37(3): 463-473.

Bregman,R.C. (1950) A mathematical model of determining the length of a tooth for root canal treatment and filling. J. Canad. dent. Ass. 16(6): 305-306.

Brin,I. and Koyoumdijsky-Kaye,E. (1981) The influence of premature extractions of primary molars on the ultimate root length of their permanent successors. J. dent. Res. 60(6): 962-965.

Brook,A.H. and Holt,R.D. (1978) The relationship of crown length to root length in permanent maxillary central incisors. Proc. Brit. paedod. Soc. 8: 17-20.

Broom,R. (1936) The dentition of Australopithecus. Nature 138: 719.

Broom,R. and Robinson,J.T. (1952) Swartkrans Ape-man: Paranthropus crassidens. Mem. Trans. Mus. no 6.

Broom,R. and Schepers,G.W.H. (1946) The South African fossil Ape-men: the Australopithecinae. Trans. Mus. Mem. no 2.

Brown,C.K. (1975) Bilateral bifurcation of the maxillary deciduous cuspids. Oral Surg. 40: 817.

Brown,R. (1950) A method of measurement of root area. J. Canad. dent. Assoc. 16(3): 130-132.

Bruszt,P. (1964) Double-rooted upper deciduous canine. Oral Surg. 17(3): 364-365.

Bryce,T.H. (1913) Teeth of primitive man. Br. dent. J. 34(3): 105-113.

Buchner,A. and Kaffe,I. (1978) An accessory root on the first mandibular molar : case report. Isr. J. Dent. Med. 27(3): 20.

Butler,P.M. (1941) A theory of the evolution of mammalian molar teeth. Am. J. Sci. 239: 421-450.

Butler,P.M. (1948) On the evolution of the skull and teeth in the Erinaceidae, with special reference to fossil material in the British Museum. Proc. zool, Soc. Lond. 118: 446-500.

Butler,P.M. (1956) The ontogeny of molar pattern. Biol. Rev. 31: 30-70.

Campbell,T.D. (1925) Dentition and palate of the Australian Aboriginal. Hassell Press, Adelaide.

Carlsen,O. (1967) Odontogenetic morphology. Sartryck Odontol. Tidschr. 75: 499-516.

Carlson,H. (1944) Studies on the rate and amount of eruption of certain human teeth. Am. J. Orthod. and Oral Surg. 30: 575-588.

Casamassino,P.S., Ettinger,R.L. and Schlenker,D.L. (1978) An unusual triad: microdontia, taurodontia and dens invaginatus. Oral Surg. 45: 107-112.

Cave,E.H.P. (1929) A new method of root measurement by x-rays. Br. dent. J. 50: 245-248.

Chang,K-C. (1962) New evidence on fossil man in China. Science 136: 749-760.

Chia,L-P. (1957) Notes on human and some other mammalian remains from Changyang. Vertebr. Paleo. 1(3): 252-257.

Chow,M.H. (1980) Bilateral double-rooted maxillary primary canines. Oral Surg. 50(3): 219.

Clark,W.E. Le Gros (1971) The antecedents of man. Edinburgh University Press 3rd Ed.

Colyer,F. (1936) Variations and diseases of the teeth of animals. John Bale, Sons and Danielsson Ltd.

Coon,C.S. (1963) The origin of races. Jonathan Cape, London pp. 1-724.

Coppens,Y. (1970) Les restes d'Hominides des series inferieures et moyennes des formations plio-villafranchiennes de l'Omo en Ethiopie. C.R. Acad. Sci., Paris 271: 2286-2289.

Coppens,Y. (1973a) Des restes d'Hominides des series inferieures et moyennes des formations plio-villafranchiennes de l'Omo en Ethiopie (recoltes 1970, 1971 et 1972 . C.R. Acad. Sci, Paris 276: 1823-1826.

Coppens,Y. (1973b) Les restes d'Hominides des series superieures des formations plio-villafranchiennes de l'Omo en Ethiopie (recoltes 1970, 1971 et 1972). C.R. Acad. Sci., Paris 276: 1981-1984.

Crabb,J.J. and Wilson,H.J. (1974) A method of measuring root areas of extracted teeth. J. Dentistry 2: 171-174.

Crawford,J.L. (1970) Concomitant taurodontism and amelogenesis imperfecta in the American Caucasian. J. Dent. Child. 37: 171-175.

Curzon,M.E.J. (1973) Three-rooted mandibular permanent molars in English Caucasians. J. dent. Res. 52(1): 181.

Curzon,M.E.J. (1974a) Three-rooted mandibular first permanent molars in Greenland Eskimo skulls. Arctic 27(2): 150-153.

Curzon,M.E.J. (1974b) Miscegenation and the prevalence of three-rooted mandibular first molars in the Baffin Eskimo. Community Dent. oral Epidemiol. 2: 130-131.

Curzon,M.E.J. and Curzon,J.A. (1971) Three-rooted mandibular molars in the Keewatin Eskimo. J. Canad. dent. Ass. 37: 71-72.

Cuvier,F. (1825) Des dents des Mammiferes consideres comme caracteres zoologiques. Paris F.-G. Levrault (cited by Butler, 1956).

Dahlberg,A.A. (1960) The dentition of the first Agriculturists (Jarmo, Iraq). Am. J. phys. Anthrop. 18: 243-256.

Day,M.H. and Leakey,R.E.F. (1973) New evidence of the genus Homo from East Rudolf, Kenya. I. Am. J. phys. Anthrop. 39(3): 341-354.

Day,M.H., Leakey,R.E.F., Walker,A.C. and Wood,B.A. (1975) New hominids from East Rudolf, Kenya, I. Am. J. phys. Anthrop. 42: 461-476.

Day,M.H., Leakey,R.E.F., Walker,A.C. and Wood,B.A. (1976) New hominids from East Turkana, Kenya. Am. J. phys. Anthrop. 45(3): 369-436.

De Jonge,Th.E. (1943) Transversale worteldeeling bij den medialen bovensnijtand. Tijdschr. v. Tandheelk. 50: 368-373.

De Jonge,Th.E. (1961a) Wurzelvariationen beim medialen oberen Incisivus des menschlichen Gebisses. Anat. Anz. 110: 63-66.

De Jonge,Th.E. (1961b) Gedanken uber die Wurzeldifferenzierung des vorderen unteren praemolaris. Ztschr. f. Morphol. u. Anthropol. 51(2): 220-235.

De Jonge,Th.E. (1965) "Doubling" of the palatal root in the second and third upper molars. Proc. Roy. Acad. Sci., Amst. Series C 68: 302-304.

De Jonge-Cohen,Th.E. (1919) A contribution to the morphogeny of the "Dens in Dente". Dent. Cosmos 61(3): 224-227.

De La Parra,C. (1953) Een eerste onderpraemolar met drie wortels. Tijdschr. v. Tandheelk 60: 287-289.

De La Parra,C. (1955) Wortelvariaties bij de mediale bovensnijtand van het menselijk gebit. Tijdschr. v. Tandheelk 62(3): 205-208.

De Magalhaes,L.E. and Magalhaes,J. (1974) Preliminary report on the number of roots of human bicuspids (premolars). Rev. Bras. de Pesquisas Med. e. Biol. 7(1): 5-11.

De Souza-Freitas,J.A., Lopes,E.S. and Casati-Alvares,L. (1971) Anatomic variations of lower first permanent molar roots in two ethnic groups. Oral Surg. 31(2): 274-278.

De Terra,M. (1905) Beitrage zu einer Odontographie der Mensschen-Rassen. Inaug. Diss., Zurich/Berlinische Verlagsanstalt, Berlin.

Despeignes,J.R. (1979) Variation in the area of intraperiodontal surfaces of human tooth roots in relation to their depth. J. Periodontol 50(12): 630-635.

Diab,M.A. and Stallard,R.E. (1965) A study of the relationship between epithelial root sheath and root development. Periodontics 3(1): 10-14.

Diamond,M (1952) Dental Anatomy. MacMillan Co., New York 3rd ed.

Diamond,M. and Applebaum,E. (1942) The epithelial sheath: histogenesis and function. J. dent. Res. 21(4): 403-411.

Drennan,M.R. (1929) Dentition of a Bushman tribe. Ann. S. Afr. Mus. 24: 61-87.

Drennan,M.R. (1945) A macrodontic Bushman skull in relationship to a Boskopoid skull with a similar dentition and large jaws. S. Afr. dent. J. 19(8): 243-247.

Dubois,E. (1924) On the principal characters of the cranium and the brain, the mandible, and the dentition of Pithecanthropus erectus. Proc. Konink. Akad, van Wetensch. Amst. 27: 265-278.

Duckworth,W.L.H. (1923) Morphology and Anthropology. Cambridge University Press.

Durr,D.P., Campos,C.A. and Ayers,C.S. (1980) Clinical significance of taurodontism. J. Am. dent. Ass. 100: 378-381.

Euler, (1939) Die Anomalien, Fehlbildungen und Verstumlungen der menschlichen Zahne. Lehmann, Munich (cited by Brabant et al, 1953).

Everett,F.G. and Fixott,H.C. (1963) Use of an incorporated grid in the diagnosis of oral roentgenograms. Oral Surg. 16: 1061-1064.

Everett,F.G., Jump,E.B., Holder,T.D. and Williams,G.C. (1958) The intermediate bifurcational ridge: a study of the morphology of the bifurcation of the lower first molar. J. dent. Res. 37: 162-169.

Fabian,H. (1928) Spezielle Anatomie des Gebisses. no 12. Klinkhardt, Leipzig (cited by Alexandersen, 1963; Pedersen, 1949).

Fitzgerald,G.M. (1947) Dental roentgenography I: an investigation in adumbration, or the factors that control geometric unsharpness. J. Am. dent. Ass. 34: 1-20.

Frederiksen,G. and Hegdahl,T. (1963) Nivaforskjellen mellom bifurkaturen og emaljecementgrensen hos dens molaris inferior primus og dens molaris inferior secundus. Den Norske Tannlaegeforenings Tidende 73(4) (cited by Kovacs, 1971).

Frisch,J.E. (1963) Dental variability in a population of Gibbon (Hylobates lar). In Dental Anthropology (ed) D. Brothwell pp 125-128.

Frisch,J.E. (1973) Taxonomic and phylogenetic uses of the study of variability in the hylobatid dentition. Symp. IV. int. Congr. Primat. 3: 128-147.

Gamer,S. and Zusman,S.H. (1967) Taurodontism in a 15 year old boy and his mother. J. S. Calif. dent. Ass. 35: 441-444.

Gardner,D.G. and Girgis,S.S. (1977) Taurodontism, short roots and external resorption, associated with short stature and a small head. Oral Surg. 44: 271-273.

Garn,S.M., Cole,P.E. and Guire,K.E. (1977) The effect of small samples on crown-size interrelationships. J. dent. Res. 56: 1474.

Garn,S.M., Cole,P.E. and Smith,B.H. (1980) The effect of sample size on crown size asymmetry. J. dent. Res. 58: 2012.

Garn,S.M., Cole,P.E. and Van Alstine,W.L. (1979) Sex discriminatory effectiveness using combinations of root lengths and crown diameters. Am. J. phys. Anth. 50: 115-118.

Garn,S.M., Lewis,A.B. and Walenga,A.J. (1968) Maximum - confidence values for the human mesiodistal crown dimensions of human teeth. Arch. Oral. Biol. 13: 841-844.

Garn,S.M., Smith,B.M. and Cole,P.E. (1980) Correlations between root length and face size. J. dent. Res. 59(2): 141.

Garn,S.M., Van Alstine,W.L. and Cole,P.E. (1978a) Root-length and crown-size correlations in the mandible. J. dent. Res. 57: 114.

Garn,S.M., Van Alstine,W.L. and Cole,P.E. (1978b) Intraindividual root-length correlations. J. dent. Res. 57(2): 270.

Garn,S.M., Van Alstine,W.L. and Cole,P.E. (1978c) Relationship between root lengths and crown diameters of corresponding teeth. J. dent. Res. 57(4): 636.

Gaunt,W.A. (1960) The vascular supply in relation to the formation of roots on the cheek teeth of the mouse. Acta. Anat. 43: 116-136.

Gher,M.E. and Vernino,A.R. (1980) Root morphology - clinical significance in pathogenesis and treatment of periodontal disease. J. Am. dent. Ass. 101(4): 627-633.

Gingerich,P.D. (1974) Size variability of the teeth in living mammals and the diagnosis of closely related sympatric fossil species. J. Paleontol 48(5): 895-903.

Gingerich,P.D. and Schoeniger,M.J. (1979) Patterns of tooth size variability in the dentition of Primates. Am. J. phys. Anth. 51: 457-466.

Goh,S.W. (1957) Variations in the morphology of mandibular premolar roots. Br. dent. J. 102: 311-314.

Gorjanovic-Kramberger,K. (1908) Ueber prismatische Molarwurzeln rezenter und diluviater Menschen. Anat. Anz. 32: 401-413.

Gorjanovic-Kramberger,K. (1909) Der Unterkiefer der Eskimos (Gronlander) als Trager primitiver Merkmale. Sitzungsber. d. Koningl. Preuss. Akad. d. Wissensch. 52: 1282-1294 (cited by Pedersen, 1949).

Grant,D. and Bernick,S. (1971) Morphodifferentiation and structure of Hertwig's root sheath in the cat. J. dent. Res. 50: 1580-1588.

Gregory,W.K. (1920/21) The origin and evolution of the human dentition. J. dent. Res. 2: 89-193; 215-283; 357-426; 607-717 3: 88-228.

Gregory,W.K. and Hellman,M. (1926) The dentition of Dryopithecus and the origin of man. Anthrop. pap. Am. Mus. nat. Hist. 28(1): 1-123.

Gron,A-M. (1962) Prediction of tooth emergence. J. dent. Res. 41(3): 573-585.

Gron,P. (1960) A geometrical evaluation of image size in dental radiography. J. dent. Res. 39(2): 289-301.

Hamernik,F.J. (1957) A ruler for measuring radiographic magnification. Med. Radiog. Photog. 33: 19.

Hamner,J.E., Witkop,C.J. and Metro,P.S. (1964) Taurodontism : report of a case. Oral Surg. 18(3): 409-418.

Harborow,G. (1934) The two-rooted mandibular canine. Br. dent. J. 56(1): 244-246.

Henry,P.J. (1970) Two-rooted central incisor. Oral Surg. 30: 380.

Hertwig,O. (1874) Archives f. Mikr. Anat. Bd. XI Suppl. (cited by Diamond and Applebaum, 1942).

Hillebrand,E. (1909) Beitrage zur Morphologie der menschlichen Zahne. Pester Medicinisch - Chirurgische Presse 45: 1 (cited by Alexandersen, 1963).

Hjelmann,G. (1929) Morphologische Beobachtungen an den Zahnen der Finnen. Acta. Soc. Med. Fenn. 11: 1-136 (cited by Alexandersen, 1963).

Hochstetter,R.L. (1975) Incidence of trifurcated mandibular first permanent molars in the population of Guam. J. dent. Res. 54(5): 1097.

Holt,R.D. and Brook,A.H. (1979) Taurodontism : a criterion for diagnosis and its prevalence in mandibular first permanent molars in a sample of 1,115 British schoolchildren. J. int. Ass. Dent. Child. 10: 41-47.

Howell,F.C. (1960) European and North West African Middle Pleistocene hominids. Curr. Anth. 1(3): 195-

Howell,F.C. (1967) Personal communication to : Blumberg et al, 1971. Am. J. phys. Anth. 34: 243-255.

Howell,F.C. (1969b) Hominid teeth from White Sands and Brown Sands localities, lower Omo basin (Ethiopia). Quaternaria 11: 47-64.

Hrdlicka,A. (1910) Contribution to the anthropology of Central and Smith Sound Eskimo. Anthrop. Pap. Am. Mus. nat. Hist. 5 part 2: 177-285 (cited by Pedersen, 1949).

Hughes,A.R. and Tobias,P.V. (1977) A fossil skull probably of the genus Homo from Sterkfontein. Nature 265: 310-312.

Hylander,W. (1969) Personal communication to : Turner,C.G. 1971. Am. J. phys. Anth. 34: 229-241.

Ingle,J.I. (1965) Endodontics. Philadelphia, Lea and Febiger (cited by Barker et al, 1973).

Jacob,T. (1972) New hominid finds in Indonesia and their affinities. Mankind 8: 176-181.

Jacob,T. (1973) Palaeoanthropological discoveries in Indonesia with special reference to the finds of the last two decades. J. hum. Evol. 2: 473-485.

Jacob,T. (1975) The pithecanthropines of Indonesia. Bull. Mem. Soc. Anthrop. Paris t2 serie XIII· 243-256.

Jakobbson,R. and Lind,V. (1973) Variation in root length of the permanent maxillary central incisor. Scand. J. dent. Res. 81: 335-338.

James,W.W. (1960) The jaws and teeth of primates. Pitman med. publ. Co.

Jepsen,A. (1963) Root surface measurement and a method for x-ray determination of root surface area. Acta. Odont. Scand. 21: 35-46.

Johanson,D. (1980) Early African hominid phylogenies: a re-evaluation. In: Current arguement on Early Man (ed) L-K Konigsson.

Johanson,D.C., Lovejoy,C.O., Kimbel,W.H., White,T.D., Ward,S.C., Bush,M.E., Latimer,B.M. and Coppens,Y. (1982) Morphology of the Miocene partial hominid skeleton (A.L. 288-1) from Hadar formation, Ethiopia. Am. J. phys. Anth. 57: 403-451.

Johanson,D.C. and White,T.D. (1979) A systematic assessment of early African hominids. Science 203: 321-330.

Johanson,D.C., White,T.D. and Coppens,Y. (1978) A new species of the genus Australopithecus (Primates:Hominidae) from the Pliocene of Eastern Africa. Kirtlandia no 28.

Johnson,A.E. (1978) Tooth size/body size in Gorilla gorilla and Pongo pygmaeus. J. dent. Res. 57(4): 608.

Jones,A.W. (1980) The incidence of the three-rooted lower first permanent molar in Malay people. Singapore dent. J. 5(1): 15-17.

Jorgensen,K.D. (1950) Macroscopic observations on the formation of the subpulpal wall. Odont. Tidskr. 58: 83-103.

Jorgensen,K.D. (1956) The deciduous dentition. Acta. Odont. Scand. A-5, 14: 1-202.

Kallay,J. (1963) A radiographic study of the Neanderthal teeth from Krapina, Croatia. In Dental Anthropology (ed) D. Brothwell pp 75-86.

Keene,H.J. (1966) A morphologic and biometric study of taurodontism in a contemporary population. Am. J. phys. Anth. 25: 208-209.

Keith,A. (1913) Problems relating to the teeth of the earlier forms of prehistoric man. Proc. roy. Soc. Med. (Odont) 6(3): 103-124.

Kelly,J.R. (1978) Birooted primary canines. Oral Surg. 46: 872.

Kenney,E.B. and Ramfjord,S.P. (1969) Patterns of root and alveolar bone growth associated with the development and eruption of teeth in rhesus monkeys. J. dent. Res. 43(2): 251-256.

Ketcham,A.H. (1927) A preliminary report of an investigation of apical root resorption of permanent teeth. Int. J. Orthod. 13: 97-127.

Ketcham,A.H. (1929) A progress report of an investigation of apical root resorption of vital permanent teeth. Int. J. Orth. Oral Surg. and Radiogr. 15: 310-317.

Kloehn,S.J. (1938) Significance of root form as determined by occulusal stress. J. Am. dent. Ass. 25: 1099-1110.

Korkhaus,G. (1929) Der erbliche Anteil an der Entstehung der Zahnwurzelform. Schweizerische Monatsschrift fur Zahnheilkunde 39(10): 601-607.

Kovacs,D.G. and Kaan,M. (1966) Osszehasonlito feluletmeresek termeszetes fogakon es lemezes fogpotlasokon. Fogoriosi Szelme 59: 42-45.

Kovacs,I. (1963) Contribution a l'etude de la morphologie ontogenetique des racines des dents humaines. Bull. Gp. int. Rech. Sc. Stomat. 6: 95-124.

Kovacs,I. (1964) Contribution a l'etude des rapports entre le developpement et la morphologie des racines des dents humaines. Bull. Gp. int. Rech. Sc. Stomat. 7: 85-120.

Kovacs,I. (1966) Le radico-diagramme : caracteristique de l'inclinaison, de la diverge, et de la courbure des racines dentaires. Bull. Gp. int. Rech. Sc. Stomat. 9: 59-90.

Kovacs,I. (1967) Contribution to the ontogenetic morphology of roots of human teeth. J. dent. Res. 46(5) supplement: 865-874.

Kovacs,I. (1971) A systematic description of dental roots. In Dental Morphology and Evolution (ed) A.A. Dahlberg pp 211-256 Univ. Chicago Press.

Kovacs,I. (1979) The surface characteristics of tooth roots and their biomechanical importance. Int. J. skeletal Res. 6: 181-192.

Kraus,B.S., Jordan,R.E. and Abrams,L. (1969) Dental anatomy and occlusion. Williams and Wilkins Co., Baltimore.

Krolls,S.O. and Donahue,A.H. (1980) Double-rooted maxillary primary canines. Oral Surg. 49(4): 379.

Kustaloglu,O.A. (1961) Australopithecus and Paranthropus dentitions. Southwestern J. Anthrop. 17: 226-238.

Laband,F. (1941) Two years' dental school work in British North Borneo; relation of diet to dental caries among natives. J. Am. dent. Ass. 28: 992-998.

Lasker,G.W. and Lee,M. (1957) Racial traits in the human teeth. J. forens. Sci. 2: 401-419.

Leakey,L.S.B. (1967) An early Miocene member of Hominidae. Nature 213: 155-163.

Leakey,L.S.B. (1968) The lower dentition of Kenyapithecus africanus. Nature 217: 827-830.

Leakey,L.S.B. (1970) 'Newly' recognised mandible of Ramapithecus. Nature 225: 199-200.

Leakey,R.E.F. (1971) Further evidence of Lower Pleistocene hominids from East Rudolf, North Kenya. Nature 231: 241-245.

Leakey,R.E.F. (1980) How many species of hominids at Lake Turkana? In: Current Argument on Early Man (ed) L-K Konigsson pp. 29-30.

Leakey,R.E.F., Mungai,J.M. and Walker,A.C. (1971) New australopithecines from East Rudolf, Kenya. Am. J. phys. Anthrop. 35(2): 175-186.

Leakey,R.E.F., Mungai,J.M. and Walker,A.C. (1972) New australopithecines from East Rudolf, Kenya (ii). Am. J. phys. Anthrop. 36: 235-252.

Leakey,R.E.F. and Walker,A.C. (1973) New australopithecines from East Rudolf, Kenya (iii). Am. J. phys. Anthrop. 39: 205-222.

Leakey,R.E.F. and Wood,B.A. (1974a) New evidence of the genus Homo from East Rudolf, Kenya (iv). Am. J. phys. Anthrop. 41: 237-244.

Leakey,R.E.F. and Wood,B.A. (1974b) A hominid mandible from East Rudolf, Kenya. Am. J. phys. Anthrop. 41: 245-250.

Le Huche,R. (1951) Quelle est la frequence de la bifidite de la racine de la canine inferieure? Rev. Stomat. 55: 656-659.

Lepkowski,W. (1879) Uber die Gefassverteilung in den Zahnen von Saugetieren. Arb. anat. Inst. Wiesbaden 8: 561-589 (cited by Butler, 1956).

Lepkowski,W. (1901) Die Verteilung der Gefasse in den Zahnen des Menschen. Arb. anat. Inst. Wiesbaden 17: 181-195 (cited by Butler, 1956).

Lester,K.S. and Boyde,A. (1970) Scanning electron microscopy of developing roots of molar teeth of the laboratory rat. J. Ultrastructure Res. 33: 80-94.

Liao,C.T. (1979) The development of root portion of molar tooth in Albino mouse. J. Osaka dent. Univ. 13(1): 31-64.

Lind,V. (1972) Short root anomaly. Scand. J. dent. Res. 80: 85-93.

Lowe,V.P.W. (1971) Root development of molar teeth in the bank vole (Clethrionomys glareolus). J. anim. Ecol. 40: 49-61.

Lundstrom,A. (1960) Asymmetries in the number and size of the teeth and their aetiological significance. Trans. Europ. orthod. Soc. : 167-185.

Lunt,P.A. (1954) A case of taurodontism in a modern european molar. Dent. Rec. 74(10): 307-312.

Lyon,M.W. (1913) Treeshrews : an account of the mammalian family Tupaiidae. Proc. U.S. natn. Mus. 45: 1-188.

Lysell,L. (1962) Taurodontism : a case report and a survey of the literature. Odont. Revy 13: 158-174.

Lysell,L. (1965) Taurodontism in both dentitions. Odont. Revy. 16: 359-362.

McCormack,D.W. (1937) Dental Roentgenology : a technical procedure for furthering the advancement toward anatomical accuracy. J. Calif. dent. Ass. 13: 89-116.

MacKinstry,E.W. (1936) Three-rooted lower first molars. Dental Cosmos 78(12): 1326.

Madeira,M.C., Hetem,S. and Bernaba,J.M. (1964) Raiz suplementar em primeiro molar inferior. Arquivos Centro de Estudos Faculdade de Odontologia 1: 129-148.

Mader,C.L. and Konzelman,J.L. (1980) Double-rooted maxillary central incisor. Oral Surg. 50(1): 99.

Mahler,P. (1973) Metric variation in the Pongid dentition. Ph.D. Thesis, Univ. Michigan.

Mangion,J.J. (1962) Two cases of taurodontism in modern human jaws. Br. dent. J. 113: 309-312.

Mason-Hing,L.R. (1963) Taurodontism. Oral Surg. 16: 305.

Massler,M. and Schour,I. (1941) Studies in tooth development. Theories of eruption. Am. J. Orth. Oral Surg. 27: 552-576.

Mayhall,J.T. (1981) Three-rooted deciduous mandibular second molars. J. Canad. dent. Ass. 47(5): 319-321.

Merbs,C.F. (1969) Personal communication to : C. Turner 1971. Am. J. phys. Anthrop. 34: 229-241.

Metro,P.S. (1965) Taurodontism : a dental rarity in modern man. Oral Surg. 20: 236-237.

Miyabara,T. (1916) An anthropological study of the masticatory system in the Japanese (1) the teeth. Dental Cosmos 58(7): 739-749.

Moorrees,C.F.A. (1957) The Aleut dentition. Harvard Univ. Press pp 1-196.

Moorrees,C.F.A. and Kent,R.L. (1981) Interrelations in the timing of root formation and tooth emergence. Proc. Finn. dent. Soc. 77: 113-117.

Moorrees,C.F.A. and Reed,R.B. (1964) Correlations among crown diameters of human teeth. Arch. oral. Biol. 9: 685-697.

Morelli,G. (1920) Uber Kandruck, Wien Vjschr. Zahnheilk H4 (cited by Jepsen, 1963).

Moss,M.L., Chase,P.S. and Howes,R.I. (1967) Comparative odontometry of the permanent post-canine dentition of American Whites and Negroes. Am. J. phys. Anthrop. 27: 125-142.

Muller,J.J. (1959) Die Wurzeloberflache menschlicher Zahne und ihre Bedeutung fur Ersatzkonstruktionen in Belastungsbereich des normalen und pathologischen Parodontiums. Schw. M. S. z. 69(3): 193-199.

Muller,J.J. (1963) Die gemessenen Kronen - und Wurzeloberflachen menschlicher Zahne und deren gemessene Zahnvolumina im Vergleich zur anatomischen Kronen - und Wurzelgrosse und ihre Bedeutung im normalen und pathologischen Parodontium. Rapports et Comm. du XVII Congres ARPA. Paris : Masson et Cie.

Naumov,V.A. (1965) On the size of the root surface in permanent human teeth. Stomatologia (Moskva) 44: 64-68.

Nelson,C.T. (1938) The teeth of the Indians of Pecos Pueblo. Am. J. phys. Anthrop. 23: 261-293.

Nicholls,J.I., Daly,C.H. and Kydd,W.L. (1974) Root surface measurement using a digital computer. J. dent. Res. 53(6): 1338-1341.

Nie,N.A., Hull,C.H., Jenkins,J.G., Steinbrenner,K. and Bent,D.H. (1977) Statistical package for the Social Sciences. McGraw-Hill

Orban,B. (1928) Growth and movement of tooth germs and teeth. J. Am. dent. Ass. 18: 1004.

Orban,B. and Mueller,E. (1929) The development of the bifurcation of multi-rooted teeth. J. Am. dent. Ass. 16: 297-319.

Oringer,M.J. (1948) Anomalies of the human dentition. Oral Surg. 1: 1119-1130.

Osborn,J.W. and Ten Cate,A.R. (1976) Advanced dental histology. 3rd ed. John Wright and Sons Ltd.

Owen,R. (1840-45) Odontography : or, a treatise on the comparative anatomy of the teeth. Hippolyte Bailliere, London.

Patterson,J.M. (1970) Bifurcated root of upper central incisor. Oral Surg. 29: 222.

Pearlman,C. (1972) Mesio-distal two-rooted premolars. Oral Surg. 33: 144.

Pearsall,W.B. (1900) Oblique-rooted maxillary teeth. Br. J. dent. Sci. 43: 728-733.

Pedersen,P.O. (1949) The East Greenland Eskimo dentition. Meddelelser Om Gronland 142: 1-244.

Peyer,B. (1968) Comparative odontology. Univ. Chicago Press.

Philippas,G.G. (1961) Influence of occlusal wear and age on formation of dentin and size of pulp chamber. J. dent. Res. 40(6): 1186-1198.

Pilbeam,D.R. (1969) Tertiary Pongidae of East Africa: evolutionary relationships and taxonomy. Peabody Mus. nat. Hist., Yale. Bulletin 31.

Pilbeam,D.R. and Zwell,M. (1972) The single species hypothesis, sexual dimorphism and variability in Early hominids. Ybk. Phys. Anthrop. 16: 69-79.

Pinenda,F. (1973) Roentgenographic investigation of the mesiobuccal root of the maxillary 1st molar. Oral Surg. 36: 253-260.

Pleshette,B.E. (1921) A three-rooted lower molar. Dent. Cosmos 63: 813.

Prasad,K.N. (1969) Observations on mid-tertiary hominoids Sivapithecus and Ramapithecus. Am. J. phys. Anthrop. 31: 11-16.

Preiswerk,G. (1905) Maladies des dents et de la bouche. J.B. Bailliere et fils, Paris (cited by Kovacs, 1963).

Pyle, (1938) Personal communication to : Pedersen,P.O 1949 The East Greenland Eskimo dentition.

Quintet,G.E. (1966) Le gradient morphogenetique responsable de la formule dentaire mammalienne. Bull. Inst. r. Sc. nat. Belg. 42(2):

Reichart,P.A. and Metah,D. (1981) Three-rooted permanent mandibular first molars in the Thai. Community Dent. Oral Epidemiol. 9: 191-192.

Remane,A. (1921) Beitrage zur Morphologie des Anthropoidengebisses. Arch. f. Naturgesch. 87, Abt. A.H. 11: 1-179 (cited by Alexandersen, 1962b).

Remane,A. (1960) Zahne und Gebiss. In Primatologia, Handbuch der Primatenkunde 3(2): 637-846. Basel, New York: S. Karger (cited by Alexandersen, 1962b).

Riesenfeld,A. (1970) The effect of environmental factors on tooth development: an experimental investigation. Acta. Anat. 77: 188-215.

Riesenfeld,A. and Siegel,M.I. (1970) The relationship between facial proportions and root length in the dentition of dogs. Am. J. phys. Anthrop. 33: 429-432.

Rightmire,G.P. (1980) Middle Pleistocene hominids from Olduvai Gorge, Northern Tanzania. Am. J. phys. Anthrop. 53: 225-241.

Ritchie,S.G. (1922-23) The dentition of the Western and Central Eskimos. Report Canad. Arctic Exped. 1913-18 vol 12 The Copper Eskimos part C: 59-66.

Roberts,G.L. (1936) Abnormal size of teeth. Br. dent. J. 60: 71.

Robinson,J.T. (1952) Some hominid features of the Ape-man dentition. Off. J. dent. Ass. S. Afr. 7: 102-113.

Robinson,J.T. (1953) Telanthropus and its phylogenetic significance. Am. J. phys. Anthrop. 11(4): 445-501.

Robinson,J.T. (1956) The dentition of the Australopithecinae. Trans. Mus. Mem. no 9.

Robinson,J.T. (1968) The origin and adaptive radiation of the Australopithecines. In Evolution und Hominisation (ed) G. Kurth pp 150-175.

Romaniuk,K, (1974) Scanning electron microscopy of root surfaces of human teeth. J. dent. Res. 53(3): 715.

Rossman,D.L. (1971) A comparison of root length of the anterior dentition from a modern population and the Krapina neanderthal remains. Am. J. phys. Anthrop. 35(2): 294.

Sauk,J.J. and Delaney,J.R. (1973) Taurodontism, diminished root formation and microcephalic dwarfism. Oral Surg. 36: 231-235.

Schoetensack,O. (1908) Der Unterkiefer des Homo heidelbergensis. W. Engelmann, Leipzig (cited by Brabant and Kovacs, 1961).

Schour,I. and Massler,M. (1940) Studies in tooth development. The growth pattern of human teeth part 1. J. Am. dent. Ass. 27: 1778-1793.

Schuman,E.L. and Brace,C.L. (1954) Metric and morphologic variations in the dentition of the Liberian Chimpanzee; comparisons with anthropoid and human dentitions. Hum. Biol. 26: 239-268.

Schwarz,R. (1931) Das Abstammungsproblem des Menschen. Die Fortschritte der Zahnheilkunde 7: 753-766 (cited by Alexandersen, 1963).

Schwerz,F. (1916) Morphologische Untersuchungen an Zahnen von Alamannen aus dem V. bis X. Jahrhundert. Arch. f. Anthrop. 15: 1 (cited by Alexandersen, 1963).

Scott,J.H. and Symons,N.B.B. (1974) Introduction to dental anatomy. Churchill Livingstone 7th ed.

Sculley,P.D. (1979) Unusual maxillary premolars. Oral Surg. 48(4): 381.

Selmer-Olsen,R. (1949) An odontometrical study on the Norwegian Lapps. Det Norske Videnskaps Akademi, Oslo.

Senyurek,M.S. (1939) Pulp cavities of molars in primates. Am. J. phys. Anthrop. 25: 119-131.

Senyurek,M.S. (1953) A study of the pulp cavities and roots of the lower premolars and molars of Prosimii, Ceboidea and Cercopithecoidea. Belleten, Ankara 17: 321-365.

Shapira,Y. and Delivanis,P. (1982) Multiple-rooted mandibular second premolars. J. Endod. 8(5): 231-232.

Shaw,J.C.M. (1928) Taurodont teeth in South African races. J. Anat. 62: 476-499.

Shaw,J.C.M. (1931) The teeth, the bony palate and the mandible in Bantu races of South Africa. John Bale, Sons and Danielsson, London.

Shifman,A. and Chanannel,I. (1978) Prevalence of taurodontism found in radiographic dental examination of 1,200 young adult Israeli patients. Community. Dent. Oral Epidemiol. 6: 200-203.

Sicher,M. (1942) Tooth eruption : Axial movement of teeth with limited growth. J. dent. Res. 21(4): 395-402.

Siegel,M.I. (1971) The differential effect of facial protrusion on root length in the dentition of baboons. Am. J. phys. Anthrop. 35(2): 295.

Siegel,M.I. (1972) The relationship between facial protrusion and root length in the dentition of baboons. Acta. Anat. 83: 17-29.

Siegel,M.I. (1978) Dentofacial relationships on sexually dimorphic populations. In: Recent advances in Primatology (eds) D.J. Chivers and K.A. Joysey, 3: 73-75.

Simpson,G.G., Roe,A. and Lewontin,R.C. (1960) Quantitative zoology. Harcourt, Brace and Co., N.Y.

Somogyi-Csizamzia,W. and Simons,A.J. (1971) Three-rooted mandibular first permanent molars in Alberta Indian children. J. Canad. dent. Ass. 37: 105-106.

Sperber,G. (1974) Morphology of the cheek teeth of early South African Hominids. Ph.D. Thesis, Univ. of Witwatersrand.

Sprinz,R. (1953) The linking tooth : a rare anomaly of a mandibular premolar. Br. dent. J. 95: 108-109.

Stein,M.R. (1936) A critique of Bolk's "Problems of Human Dentition". J. dent. Res. 15: 101-136.

Stenvick,A. and Svatun,B. (1972) Taurodontism and concomitant hypodontia in siblings. Oral Surg. 33: 841-845.

Stoy,P.J. (1960) Taurodontism associated with other dental abnormalities. Dent. Pract. 10: 202-205.

Swindler,D.R. (1976) Dentition of living primates. Academic Press.

Tamse,A. and Kaffe,I. (1981) Radiographic survey of the prevalence of conical lower second molar. Int. Endod. J. 14: 188-190.

Taylor,A.E. (1899) Variations in the human tooth-form as met with in isolated teeth. J. Anat. Physiol. 33: 268-272.

Tekkaya,I. (1974) A new species of Tortonian Anthropoid (Primates, Mammalia) from Anatolia. Bull. Min. Res. Exp. Inst. Turkey. 83: 148-165.

Tennant,R.D. (1966) Taurodontism. Dent. Dig. 72: 355-357.

Thews,M.E., Kemp,W.B. and Jones,C.R. (1979) Aberrations in palatal root and root canal morphology of two maxillary first molars. J. Endodontics 5(3): 94-96.

Tilk,M.A., Lommel,T.J. and Gerstein,H. (1979) A study of mandibular and maxillary root widths to determine dowel size. J. Endodontics 5(3): 79-82.

Tobias,P.V. (1955) Taurodontism in a Bushman skull from Kimberley. Br. dent. J. 98: 352-355.

Tobias,P.V. (1967) Olduvai Gorge vol II: the cranium of Australopithecus (Zinjanthropus) boisei. Cambridge University Press.

Tobias,P.V. (1980) 'Australopithecus afarensis' and A. africanus: critique and an alternative hypothesis. Palaeont. afr. 23: 1-17.

Todd,T.W. (1915) The teeth of primitive man. Cleveland Med. J. 14: 253-264.

Tomes,C. (1923) Manual of dental anatomy. 8th ed (ed) Marrett Tims. J. and A. Churchill.

Tratman,E.K. (1938) Three-rooted lower molars in man and their racial distribution. Br. dent. J. 64: 264-274.

Tratman,E.K. (1950) A comparison of the teeth of people: Indo-European racial stock with the Mongoloid racial stock. Dental Record 70:

Turner,C.G. (1971) Three-rooted mandibular first permanent molars and the question of American Indian origins. Am. J. phys. Anthrop. 34: 229-241.

Turner,C.G. (1981) Root number determination in maxillary first premolars for modern human populations. Am. J. phys. Anthrop. 54: 59-62.

Tylman,S.D. and Tylman,S.G. (1960) Theory and practice of crown and bridge prosthodontics. C.V. Mosby Co., St. Louis.

Vallois,H. (1956) The pre-Mousterian human mandible from Montmaurin. Am. J. phys. Anthrop. 14: 319-323.

Visser,J.B. (1943a) Uber Wurzelverschmelzungen an den Oberen Molaren des Menschlichen Gebisses. Acta Neerlandica Morphologiae 5: 1-10.

Visser,J.B. (1943b) Wurzelverschmelzungen der oberen praemolaren des Menschlichen Gebisses. Acta Neerlandica Morphologiae 5: 184-188.

Visser,J.B. (1948) Beitrag zur Kenntnis der menschlichen Zahnwurzelform. Diss. Rotting, Hilversum.

Von Brunn,A (1887) Ueber die Ansdehnung des Schmelzorganes und seine Bedeutung fur die Zahnbildung. Arch. mikr. Anat. 29: 367-383 (cited by Butler, 1956).

Von Brunn,A. (1891) Beitrage zur Kenntnis der Zahnentwickelung. Arch. mikr. Anat. 38: 142-156 (cited by Butler, 1956).

Von Koenigswald,G.H.R. (1968) Observations upon two Pithecanthropus mandibles from Sangiran, Central Java. Proc. Konink. Ned. Akad. van Wetens. B71: 99-107.

Von Koenigswald,G.H.R. (1969) Java : prae-Trinil man. Proc. VIII Int. Congr. Anthrop. Ethnol. Sci, 1968, Tokyo/Kyoto 1: 104-105.

Ward,S.C. (1978) Mandibular alveolar process proportions and dental root angulation in cercopithecoid primates. Am. J. phys. Anthrop. 48: 446.

Ward,S.C. (1979) Subocclusal dental morphology of Pliocene hominid mandibles from the Hadar Formation. Am. J. phys. Anthrop. 50: 490.

Ward,S.C., Johanson,D.C. and Coppens,Y. (1982) Subocclusal morphology and alveolar process relationships of hominid gnathic elements from the Hadar Formation: 1974-77 collections. Am. J. phys. Anthrop. 57: 605-630.

Ward,S.C. and Molnar,S. (1980) Experimental stress analysis of topographic diversity in early hominid gnathic morphology. Am. J. phys. Anthrop. 53: 383-395.

Watt,D.M., MacGregor,A.R., Geddes,M., Cockburn,A. and Boyd,J.L. (1958) A preliminary investigation of the support of partial dentures and its relationship to vertical loads. Dent. Pract. 9: 2-15.

Weidenreich,F. (1937) The dentition of Sinanthropus pekinensis: a comparative odontography of the hominids. Palaeont. Sinica, New Series D, no 1. Whole Series 101.

Weidenreich,F. (1945) Giant early man from Java and South China. Anthrop. pap. Am. Mus. Nat. Hist. 40(1)

White,T.D. (1977) New fossil hominids from Laetoli, Tanzania. Am. J. phys. Anthrop. 46(2): 197-230.

White,T.D. (1980) Additional fossil hominids from Laetoli, Tanzania: 1976-79 specimens. Am. J. phys. Anthrop. 53: 487-504.

White,T.D., Johanson,D.C. and Kimbel,W.H. (1981) Australopithecus africanus: its phyletic position reconsidered. S. Afr. J. Sci. 77: 445-470.

Woo,J-K. (1962) The mandibles and dentition of Gigantopithecus. Palaeont. Sin. New series D, no. 11, whole number 146.

Woo,J-K. and Chia,L.P. (1954) New discoveries about Sinanthropus pekinensis in Choukoutien. Scientia Sin. 3: 335-351.

Wright,K.E. (1977) The use of dental morphology to identify an Ontario Iroquois ossuary population. M.A. Thesis, McMaster Univ. Hamilton (cited by Turner, 1981).

Zaslawsky,J. (1937) Seltene Anomalie eines zweiwurzeligen oberen, rechten, zentralen Schneidezahnes. Zeitschr. f. Stomat. 35: 1067-1068.

Part VI : Appendices

Appendix A : The comparative samples

Appendix B : The fossil hominid sample

Appendix C : The root, crown and jaw variables

Appendix D : Statistical summaries for the root, crown and jaw dimensions in the comparative samples (pooled sexes)

Appendix E : Statistical summaries for the indices computed from root, crown and jaw dimensions in the pongids and *Homo sapiens* (pooled sexes)

Appendix F : Statistical tests of significance for the mean values and variances of the root, crown and jaw dimensions and indices in the comparative samples

Appendix G : Statistical summaries for the root, crown and jaw dimensions in the males and females of each comparative sample

Appendix H : Statistical summaries for the indices computed from root, crown and jaw dimensions in the males and females of the pongids and *Homo sapiens*

Appendix I : Correlation coefficients computed between root height and other root, crown and jaw variables in the pongids and *Homo sapiens*

Appendix J : Mandibular premolar root form in the fossil hominid sample

Appendix K : The root and crown dimensions and indices in the fossil hominid sample

Appendix L : Published root dimensions for early fossil hominids

Appendix M : Statistical summaries for the root and crown dimensions and indices in the fossil hominid groups

Appendix A : The Comparative Samples

Gorilla gorilla : 23 males and 17 females

Males	Females
B.M.(N.H.) :	B.M.(N.H.) :
A.25	A.D.4
A.26	23.11.29.5
A.D.42	49.664
S.S.28.4.1919(i)	1916.11.11.1
S.S.28.4.1919(ii)	1939.914
22.2.10.1	1939.925
23.11.29.1	1939.927
23.11.29.7	1939.934
29.1.1.1	1939.953
49.603	1939.956
78.12.14.1	1948.3.31.1
1939.913	1949.4.1.2
1939.923	1949.12.20.2
1939.926	1951.9.27.12
1939.932	1951.9.27.14
1939.938	1951.9.27.20
1939.939	1979.1322
1939.942	
1948.2.27.1	
1948.3.3.2	
1948.5.4.1	
1948.5.4.2	
1961.4.5.1	

Pan troglodytes : 20 males and 11 females

Males	Females
B.M.(N.H.) :	B.M.(N.H.) :
2a	20.4.13.2
7.7.8.19	23.3.1.1
17.12.16.1	27.1.4.1
22.12.19.2	88.1.28.18
50.1863	1864.12.1.7
76.1797	1939.992
87.12.1.2	1939.3366
1884.9.18.1	1939.3378
1901.8.9.10	1939.3379
1922.12.19.1	1939.3382
1939.951	1939.3383
1939.957	
1939.3363	
1939.3364	
1939.3365	
1939.3369	
1939.3377	
1939.3384	
1948.10.25.2	
1969.7.5.7	

Pongo pygmaeus : 19 males and 15 females

Males	Females
M.B.(N.H.) :	B.M.(N.H.) :
3.e.e.(1100/Brooke 6)	3m.(1099/Brooke 9)
3.i.(1080/Brooke 13)	3.0
3.j.(1079/Brooke 14)	1179.c.
18.5.23.1	1879.11.21.214
1844.3.30.18	1939.1007
1879.11.21.213	1948.7.6.1
1898.2.28.11	1948.10.30.1
1939.1008	1948.11.23.1
1939.1017	1976.1409
1939.1018	1976.1418
1939.1019	1976.1421
1948.7.6.3	1976.1422
1948.10.25.1	1976.1423
1976.1426	1976.1427
1976.1432	1976.1430
1976.1435	
1976.1439	
1976.1442	
1976.1443	

Homo sapiens sapiens : 16 males and 18 females

Males	Females
Romano-British	
B.M.(N.H.) :	B.M.(N.H.) :
PC69B/88	PC69B/100
PC69B/94	PC70B/172
PC69B/98	PC70B/235
PC69B/119	PC70C/197
PC70C/190	PC71B/283
PC71B/165	PC71B/309
PC71B/170	PC71C/413
PC71B/255	PC71D/395
PC71B/284	PC72C/543
PC71B/290	PC72C/566
Australian Aborigine	
B.M.(N.H.) :	B.M.(N.H.) :
97.10.10.3	1888.12.10.1
1960.9.91	Aus 30/981
Aus 30/53	Aus 30/982
Aus 30/439	Aus 30/983
Aus 50/532	Aus 30/984
Aus 60/2	Aus 50/994
	Aus 60/1004
	Aus 60/1007

Appendix B : The fossil hominid sample

	Museum specimen No.
Koobi Fora:	KNM-ER 403
	KNM-ER 404
	KNM-ER 725
	KNM-ER 726
	KNM-ER 727
	KNM-ER 728
	KNM-ER 729
	KNM-ER 730
	KNM-ER 733
	KNM-ER 801
	KNM-ER 810
	KNM-ER 818
	KNM-ER 819
	KNM-ER 820
	KNM-ER 992
	KNM-ER 1468
	KNM-ER 1482
	KNM-ER 1483
	KNM-ER 1501
	KNM-ER 1502
	KNM-ER 1506
	KNM-ER 1507
	KNM-ER 1508
	KNM-ER 1801
	KNM-ER 1802
	KNM-ER 1803
	KNM-ER 1805
	KNM-ER 1806
	KNM-ER 1808
	KNM-ER 1811
	KNM-ER 1812
	KNM-ER 2597
	KNM-ER 3229
	KNM-ER 3230
	KNM-ER 3729

KNM-ER 3731
KNM-ER 3734
KNM-ER 3889
KNM-ER 3954
KNM-ER 5429

Laetoli : L.H.4
L.H.10
L.H.14

Olduvai Gorge : O.H.7
O.H.13
O.H.16
O.H.22
O.H.23
O.H.37
O.H.51

Peninj : Peninj 1

Appendix C : The root, crown and jaw variables

R = root diagram; S = specimen; 1R = one rooted; 2T = Tomes' root; 2R - two rooted; 3R = three rooted.

1	I_1	:	Neck mesiodistal diameter (R)
2			Projected root height (R)
3			Actual root height (R)
4			Root angulation (R)
5			Crown mesiodistal diameter (S)
6			Crown buccolingual diameter (S)
7	I_2	:	Neck mesiodistal diameter (R)
8			Projected root height (R)
9			Actual root height (R)
10			Root angulation (R)
11			Crown mesiodistal diameter (S)
12			Crown buccolingual diameter (S)
13	C_1	:	Neck width (R)
14			Root height (R)
15			Root width (R)
16			Crown mesiodistal diameter (S)
17			Crown buccolingual diameter (S)
18	P_3	:	Neck mesiodistal diameter (R)
19			Root number
20			2R - height of bifurcation (R)
21			2R - location of bifurcation (R)
22			2T/2R - projected height mesiobuccal/mesial root (R)
23			2T/2R - actual height mesiobuccal/mesial root (R)
24			2T/2R - mesiobuccal/mesial root mesiodistal diameter (R
25			2T/2R - angulation mesiobuccal/mesial root (R)
26			2T/2R - projected height distolingual/distal root (R)
27			2T/2R - actual height distolingual/distal root (R)
28			2T/2R - distolingual/distal root mesiodistal diameter(R
29			2T/2R - angulation distolingual/distal root (R)
30			1R - projected root height (R)
31			1R - actual root height (R)
32			1R - root mesiodistal diameter (R)
33			1R - root angulation (R)
34			Crown mesiodistal diameter (S)
35			Crown buccolingual diameter (S)

36 P_4 : Neck mesiodistal diameter (R)
37 Root number
38 2R - height of bifurcation (R)
39 2R - location of bifurcation (R)
40 2T/2R - projected height mesiobuccal/mesial root (R)
41 2T/2R - actual height mesiobuccal/mesial root (R)
42 2T/2R - mesiobuccal/mesial root mesiodistal diameter(R)
43 2T/2R - angulation mesiobuccal/mesial root (R)
44 2T/2R - projected height distolingual/distal root (R)
45 2T/2R - actual height distolingual/distal root (R)
46 2T/2R - distolingual/distal root mesiodistal diameter(F
47 2T/2R - angulation distolingual/distal root (R)
48 1R - projected root height (R)
49 1R - actual root height (R)
50 1R - root mesiodistal diameter (R)
51 1R - root angulation (R)
52 Crown mesiodistal diameter (S)
53 Crown buccolingual diameter (S)
54 M_1 : Neck mesiodistal diameter (R)
55 Height of bifurcation (R)
56 Location of bifurcation (R)
57 Projected height mesial root (R)
58 Actual height mesial root (R)
59 Mesial root mesiodistal diameter (R)
60 Angulation mesial root (R)
61 Projected height distal root (R)
62 Actual height distal root (R)
63 Distal root mesiodistal diameter (R)
64 Angulation distal root (R)
65 Crown mesiodistal diameter (S)
66 Crown buccolingual diameter (S)
67 M_2 : Neck mesiodistal diameter (R)
68 Height of bifurcation (R)
69 Location of bifurcation (R)
70 Projected height mesial root (R)
71 Actual height mesial root (R)
72 Mesial root mesiodistal diameter (R)
73 Angulation mesial root (R)
74 Projected height distal root (R)

75 Actual height distal root (R)
76 Distal root mesiodistal diameter (R)
77 Angulation distal root (R)
78 Crown mesiodistal diameter (S)
79 Crown buccolingual diameter (S)
80 $\underline{M}_{3}$: Neck mesiodistal diameter (R)
81 Height of bifurcation (R)
82 Location of bifurcation (R)
83 Projected height mesial root (R)
84 Actual height mesial root (R)
85 Mesial root mesiodistal diameter (R)
86 Angulation mesial root (R)
87 Projected height distal root (R)
88 Actual height distal root (R)
89 Distal root mesiodistal diameter (R)
90 Angulation distal root (R)
91 Crown mesiodistal diameter (S)
92 Crown buccolingual diameter (S)
93 $\underline{I}^{1}$: Neck mesiodistal diameter (R)
94 Projected root height (R)
95 Actual root height (R)
96 Root angulation (R)
97 Crown mesiodistal diameter (S)
98 Crown buccolingual diameter (S)
99 $\underline{I}^{2}$: Neck mesiodistal diameter (R)
100 Projected root height (R)
101 Actual root height (R)
102 Root angulation (R)
103 Crown mesiodistal diameter (S)
104 Crown buccolingual diameter (S)
105 $\underline{P}^{3}$: Root number
106 3R - projected height lingual root (R)
107 3R - actual height lingual root (R)
108 3R - lingual root mesiodistal diameter (R)
109 3R - angulation lingual root (R)
110 3R - height of bifurcation (R)
111 3R - location of bifurcation (R)
112 3R - projected height mesiobuccal root (R)
113 3R - actual height mesiobuccal root (R)
114 3R - mesiobuccal root mesiodistal diameter (R)

115 3R - angulation mesiobuccal root (R)
116 3R - projected height distobuccal root (R)
117 3R - actual height distobuccal root (R)
118 3R - distobuccal root mesiodistal diameter (R)
119 3R - angulation distobuccal root (R)
120 2R - projected height lingual root (R)
121 2R - actual height lingual root (R)
122 2R - lingual root mesiodistal diameter (R)
123 2R - angulation lingual root (R)
124 2R - projected height buccal root (R)
125 2R - actual height buccal root (R)
126 2R - buccal root mesiodistal diameter (R)
127 2R - angulation buccal root (R)
128 1R - projected root height (R)
129 1R - actual root height (R)
130 1R - root mesiodistal diameter (R)
131 1R - root angulation (R)
132 Crown mesiodistal diameter (S)
133 Crown buccolingual diameter (S)
134 $P\frac{4}{}$: Root number
135 3R - projected height lingual root (R)
136 3R - actual height lingual root
137 3R - lingual root mesiodistal diameter (R)
138 3R - angulation lingual root (R)
139 3R - height of bifurcation (R)
140 3R - location of bifurcation (R)
141 3R - projected height mesiobuccal root (R)
142 3R - actual height mesiobuccal root (R)
143 3R - mesiobuccal root mesiodistal diameter (R)
144 3R - angulation mesiobuccal root (R)
145 3R - projected height distobuccal root (R)
146 3R - actual height distobuccal root (R)
147 3R - distobuccal root mesiodistal diameter (R)
148 3R - angulation distobuccal root (R)
149 2R - projected height lingual root (R)
150 2R - actual height lingual root (R)
151 2R - lingual root mesiodistal diameter (R)
152 2R - angulation lingual root (R)
153 2R - projected height buccal root (R)
154 2R - actual height buccal root (R)

155 2R - buccal root mesiodistal diameter (R)
156 2R - angulation buccal root (R)
157 1R - projected root height (R)
158 1R - actual root height (R)
159 1R - root mesiodistal diameter (R)
160 1R - root angulation (R)
161 Crown mesiodistal diameter (S)
162 Crown buccolingual diameter (S)
163 M^{1} : Projected height lingual root (R)
164 Actual height lingual root (R)
165 Lingual root mesiodistal diameter (R)
166 Angulation lingual root (R)
167 Height of bifurcation (R)
168 Location of bifurcation (R)
169 Projected height mesiobuccal root (R)
170 Actual height mesiobuccal root (R)
171 Mesiobuccal root mesiodistal diameter (R)
172 Angulation mesiobuccal root (R)
173 Projected height distobuccal root (R)
174 Actual height distobuccal root (R)
175 Distobuccal root mesiodistal diameter (R)
176 Angulation distobuccal root (R)
177 Crown mesiodistal diameter (S)
178 Crown buccolingual diameter (S)
179 M^{2} : Root number
180 Projected height lingual root (R)
181 Actual height lingual root (R)
182 Lingual root mesiodistal diameter (R)
183 Angulation lingual root (R)
184 Height of bifurcation (R)
185 Location of bifurcation (R)
186 Projected height mesiobuccal root (R)
187 Actual height mesiobuccal root (R)
188 Mesiobuccal root mesiodistal diameter (R)
189 Angulation mesiobuccal root (R)
190 Projected height distobuccal root (R)
191 Actual height distobuccal root (R)
192 Distobuccal root mesiodistal diameter (R)
193 Angulation distobuccal root (R)
194 Crown mesiodistal diameter (S)

195 Crown buccolingual diameter (S)
196 M^3 : Root number
197 Projected height lingual root (R)
198 Actual height lingual root (R)
199 Lingual root mesiodistal diameter (R)
200 Angulation lingual root (R)
201 Height of bifurcation (R)
202 Location of bifurcation (R)
203 Projected height mesiobuccal root (R)
204 Actual height mesiobuccal root (R)
205 Mesiobuccal root mesiodistal diameter (R)
206 Angulation mesiobuccal root (R)
207 Projected height distobuccal root (R)
208 Actual height distobuccal root (R)
209 Distobuccal root mesiodistal diameter (R)
210 Angulation distobuccal root (R)
211 Crown mesiodistal diameter (S)
212 Crown buccolingual diameter (S)
213 Palatal length (S)
214 Palatal breadth (S)
215 Mandibular length (S)
216 Mandibular depth $C_{\overline{1}}$ (S)
217 Mandibular depth $M_{\overline{1}}$ (S)
218 Mandibular depth $M_{\overline{2}}$ (S)
219 Mandibular depth $M_{\overline{3}}$ (S)

Appendix D: Statistical summaries for the root, crown and jaw dimensions in the comparative samples (pooled sexes)

D (i) : Neck mesiodistal diameter

D (ii) : Location of bifurcation

D (iii) : Actual root height

D (iv) : Projected root height

D (v) : Root mesiodistal diameter

D (vi) : Height of bifurcation

D (vii) : Root angulation

D (viii) : Crown mesiodistal diameter

D (ix) : Crown buccolingual diameter

D (x) : Jaw dimensions

D(i): Neck mesiodistal diameter

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$I_{\bar{1}}$							
Gorilla	5.4	0.09	0.5	4.1	6.3	9.1	30
Pan	5.1	0.09	0.5	4.3	6.2	8.9	26
Pongo	5.6	0.09	0.5	4.8	7.0	8.8	31
H.sapiens (pooled)	3.5	0.09	0.5	2.7	4.4	13.3	25
Romano-British	3.2	0.06	0.2	2.7	3.7	7.1	17
Aust.Aborigines	4.0	0.13	0.4	3.5	4.4	9.0	8
$I_{\bar{2}}$							
Gorilla	5.9	0.12	0.7	4.2	7.6	11.9	36
Pan	5.5	0.11	0.5	4.6	7.0	9.7	26
Pongo	6.0	0.12	0.7	5.2	8.0	11.0	31
H.sapiens (pooled)	4.0	0.11	0.6	3.1	5.6	15.2	30
Romano-British	3.7	0.08	0.4	3.1	4.4	9.9	20
Aust.Aborigines	4.7	0.17	0.5	3.9	5.6	11.4	10
$C_{\bar{1}}$							
Gorilla	12.4	0.47	2.7	8.7	19.1	21.8	33
Pan	10.5	0.31	1.7	7.2	13.2	16.1	30
Pongo	11.1	0.33	1.8	8.0	14.1	15.9	29
H.sapiens (pooled)	6.5	0.15	0.8	4.8	8.2	13.0	31
Romano-British	6.1	0.17	0.8	4.8	7.2	12.2	19
Aust.Aborigines	7.0	0.19	0.7	6.3	8.2	9.6	12
$P_{\bar{3}}$							
Gorilla	13.8	0.24	1.5	11.1	16.8	10.8	40
Pan	8.6	0.18	1.0	6.6	11.5	11.6	31
Pongo	11.7	0.23	1.4	9.1	15.1	11.6	34
H.sapiens (pooled)	5.3	0.11	0.6	4.2	6.9	12.2	32
Romano-British	5.0	0.09	0.4	4.2	5.5	7.7	20
Aust.Aborigines	5.8	0.19	0.7	4.7	6.9	11.4	12
$P_{\bar{4}}$							
Gorilla	11.1	0.16	1.0	9.1	14.0	9.1	39
Pan	7.4	0.12	0.7	6.0	8.8	9.1	31
Pongo	10.0	0.16	0.9	8.0	12.0	9.2	34
H.sapiens (pooled)	5.3	0.10	0.6	4.5	6.8	10.8	33
Romano-British	5.1	0.09	0.4	4.5	5.9	8.3	20
Aust.Aborigines	5.7	0.15	0.6	4.8	6.8	9.7	13

D(i): Neck mesiodistal diameter

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$M_{\bar{1}}$							
Gorilla	14.8	0.20	1.2	11.9	17.7	8.4	40
Pan	9.9	0.11	0.6	8.5	11.0	6.4	31
Pongo	11.9	0.15	0.9	10.5	13.6	7.3	34
H.sapiens (pooled)	9.6	0.15	0.9	7.9	11.7	9.0	33
Romano-British	9.2	0.16	0.7	7.9	10.2	7.8	20
Aust. Aborigines	10.3	0.18	0.7	9.3	11.7	6.3	13
$M_{\bar{2}}$							
Gorilla	16.1	0.21	1.3	13.0	19.1	8.2	40
Pan	10.4	0.13	0.7	9.4	13.0	6.7	31
Pongo	12.7	0.17	1.0	10.8	14.9	7.8	34
H.sapiens (pooled)	9.5	0.20	1.2	7.7	12.6	12.5	34
Romano-British	8.8	0.16	0.7	7.7	10.1	8.0	20
Aust.Aborigines	10.5	0.29	1.1	9.0	12.6	10.2	14
$M_{\bar{3}}$							
Gorilla	15.7	0.22	1.4	12.5	19.7	8.6	39
Pan	9.7	0.11	0.6	8.8	11.3	6.5	31
Pongo	12.3	0.20	1.1	10.1	14.2	9.2	34
H.sapiens (pooled)	9.7	0.17	0.9	8.3	11.8	9.5	29
Romano-British	9.0	0.14	0.6	8.3	10.0	6.0	16
Aust.Aborigines	10.4	0.19	0.7	9.4	11.8	6.4	13
I_{-}^{1}							
Gorilla	9.9	0.19	1.0	7.1	11.4	10.4	31
Pan	8.5	0.13	0.7	7.2	10.9	8.3	28
Pongo	9.9	0.17	0.9	8.1	11.7	9.5	29
H.sapiens (pooled)	6.0	0.11	0.5	5.3	7.0	8.9	25
Romano-British	5.8	0.11	0.5	5.3	7.0	8.3	19
Aust.Aborigines	6.5	0.13	0.3	6.1	7.0	4.7	6
I_{-}^{2}							
Gorilla	7.0	0.19	1.0	5.2	9.6	13.5	26
Pan	6.3	0.10	0.5	5.5	7.7	7.7	25
Pongo	6.2	0.12	0.7	5.0	7.7	10.6	30
H.sapiens (pooled)	5.2	0.14	0.8	4.0	6.7	14.6	29
Romano-British	4.7	0.10	0.4	4.0	5.5	9.1	17
Aust.Aborigines	5.9	0.16	0.6	5.2	6.7	9.5	12

D(ii): Location of bifurcation

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$2RP_{\bar{3}}$							
Gorilla	7.0	0.15	0.9	5.2	9.1	13.3	40
Pan	4.7	0.11	0.5	3.8	6.0	11.4	22
Pongo	6.2	0.13	0.8	4.9	8.5	12.5	33
Aust.Aborigines	3.4	–	–	–	–	–	1
$2RP_{\bar{4}}$							
Gorilla	5.1	0.08	0.5	4.3	6.8	9.6	39
Pan	3.6	0.07	0.4	2.8	4.8	10.8	31
Pongo	4.8	0.09	0.6	3.8	6.3	11.5	34
$M_{\bar{1}}$							
Gorilla	6.9	0.11	0.7	5.6	8.6	10.4	40
Pan	5.0	0.08	0.5	4.2	5.9	9.3	31
Pongo	5.9	0.09	0.5	4.7	6.8	9.2	34
H. sapiens (pooled)	5.0	0.09	0.5	3.9	5.7	10.4	33
Romano-British	4.8	0.12	0.5	3.9	5.7	11.2	20
Aust.Aborigines	5.3	0.08	0.3	4.7	5.6	5.7	13
$M_{\bar{2}}$							
Gorilla	7.7	0.13	0.8	6.4	10.1	10.4	40
Pan	5.2	0.07	0.4	4.4	6.2	7.9	31
Pongo	6.3	0.10	0.6	5.4	7.4	9.2	34
H.sapiens (pooled)	4.8	0.11	0.6	3.8	6.3	12.7	33
Romano-British	4.5	0.16	0.4	3.8	5.6	9.8	19
Aust.Aborigines	5.2	0.16	0.6	4.2	6.3	11.2	14
$M_{\bar{3}}$							
Gorilla	7.6	0.12	0.7	5.8	8.8	9.6	39
Pan	5.0	0.09	0.5	3.7	5.8	10.4	31
Pongo	6.3	0.11	0.6	4.7	7.4	10.1	34
H.sapiens (pooled)	5.0	0.12	0.6	4.1	6.0	12.1	28
Romano-British	4.6	0.14	0.4	4.1	5.4	7.9	15
Aust.Aborigines	5.5	0.13	0.5	4.6	6.0	8.5	13
$3RP^{\bar{3}}$							
Gorilla	5.6	0.11	0.7	4.7	8.0	12.0	39
Pan	3.4	0.12	0.6	1.8	4.8	17.9	27
Pongo	4.2	0.16	0.8	2.8	5.5	18.2	24
$3RP^{\bar{4}}$							
Gorilla	4.3	0.13	0.8	3.0	6.6	18.7	40
Pan	2.5	0.31	0.7	1.4	3.2	27.6	5
Pongo	3.5	0.16	0.8	1.9	5.8	23.6	27

D(11): Location of bifurcation

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
M^1							
Gorilla	5.9	0.14	0.9	4.6	8.5	14.6	40
Pan	3.8	0.07	0.4	3.0	4.6	10.6	31
Pongo	5.1	0.11	0.6	4.0	7.2	12.4	32
H.sapiens (pooled)	4.1	0.11	0.6	3.1	5.4	14.6	31
Romano-British	3.9	0.12	0.5	3.1	5.0	12.6	18
Aust.Aborigines	4.5	0.16	0.6	3.8	5.4	12.9	13
M^2							
Gorilla	6.2	0.15	0.9	4.7	9.1	14.1	36
Pan	3.8	0.11	0.6	2.8	5.3	15.6	30
Pongo	4.8	0.13	0.7	3.7	7.4	14.2	29
H.sapiens (pooled)	4.3	0.10	0.5	3.4	5.3	11.6	28
Romano-British	4.2	0.14	0.5	3.4	4.9	12.1	14
Aust.Aborigines	4.4	0.13	0.5	3.4	5.3	11.3	14
M^3							
Gorilla	6.2	0.14	0.9	4.7	8.1	13.7	37
Pan	3.6	0.10	0.6	2.2	4.9	15.6	30
Pongo	4.3	0.15	0.7	3.4	6.0	16.4	24
H.sapiens (pooled)	4.7	0.32	1.1	3.1	7.3	23.4	12
Romano-British	4.0	–	–	3.1	4.5	–	4
Aust.Aborigines	5.1	0.40	1.1	3.7	7.3	22.2	8

D(iii): Actual root height

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$I_{\bar{1}}$							
Gorilla	20.9	0.50	2.6	17.3	28.8	12.6	28
Pan	16.7	0.33	1.7	13.2	19.1	10.0	26
Pongo	21.2	0.45	2.5	17.2	27.3	11.7	31
H.sapiens (pooled)	13.0	0.35	1.8	10.2	17.2	13.7	25
Romano-British	12.4	0.34	1.4	10.2	15.4	11.5	17
Aust.Aborigines	14.2	0.66	1.9	11.7	17.2	13.2	8
$I_{\bar{2}}$							
Gorilla	22.6	0.40	2.4	17.9	28.1	10.6	36
Pan	17.4	0.44	2.3	11.9	22.4	12.9	26
Pongo	22.3	0.46	2.5	17.9	29.3	11.4	31
H.sapiens (pooled)	14.4	0.33	1.8	10.7	18.9	12.6	30
Romano-British	14.3	0.33	1.5	12.3	18.8	10.2	20
Aust.Aborigines	14.6	0.77	2.5	10.7	18.9	16.7	10
$C_{\bar{1}}$							
Gorilla	33.1	0.75	4.1	24.6	41.7	12.5	30
Pan	28.6	0.89	4.6	20.7	35.9	16.2	27
Pongo	34.6	1.73	6.7	24.1	45.2	19.4	15
H.sapiens (pooled)	17.7	0.52	2.9	12.6	25.5	16.4	31
Romano-British	16.4	0.45	2.0	12.6	20.0	11.9	19
Aust.Aborigines	19.7	0.89	3.1	14.8	25.5	15.7	12
$2RP_{\bar{3}}$ m							
Gorilla	22.7	0.46	2.9	18.2	29.6	12.7	39
Pan	18.2	0.54	2.5	12.5	23.4	14.0	22
Pongo	25.5	0.64	3.5	19.6	33.5	13.7	30
Aust.Aborigines	16.3	–	–	–	–	–	1
$2RP_{\bar{3}}$ d							
Gorilla	22.0	0.51	3.2	17.2	32.0	14.4	39
Pan	17.5	0.48	2.3	12.2	20.8	12.9	22
Pongo	23.5	0.70	3.8	16.3	33.0	16.3	30
Aust.Aborigines	15.8	–	–	–	–	–	1
$1RP_{\bar{3}}$							
Pan	17.6	0.62	1.9	15.5	20.6	10.6	9
Pongo	25.0	–	–	–	–	–	1
H.sapiens (pooled)	15.7	0.35	1.9	12.6	21.2	12.4	31
Romano-British	15.0	0.33	1.5	12.6	18.5	9.7	20
Aust.Aborigines	16.8	0.67	2.2	13.2	21.2	13.1	11

D(iii): Actual root height

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$2RP\frac{}{4}$ m							
Gorilla	20.6	0.33	2.0	15.3	24.3	9.7	37
Pan	17.1	0.40	2.3	12.4	23.0	13.2	31
Pongo	22.9	0.64	3.6	14.8	31.5	15.9	32
$2RP\frac{}{4}$ d							
Gorilla	20.9	0.30	1.9	17.3	25.0	9.0	38
Pan	16.7	0.34	1.9	12.8	20.7	11.4	31
Pongo	22.1	0.59	3.3	15.2	31.8	15.1	32
$1RP\frac{}{4}$							
H.sapiens (pooled)	15.9	0.36	2.1	12.4	21.4	13.2	33
Romano-British	15.4	0.45	2.0	12.4	19.2	13.2	20
Aust.Aborigines	16.7	0.55	2.0	13.6	21.4	11.9	13
$M\frac{}{1}$ m							
Gorilla	18.2	0.38	2.4	13.0	24.1	13.1	40
Pan	13.2	0.27	1.5	10.7	16.0	11.2	31
Pongo	20.5	0.47	2.8	14.7	25.7	13.5	34
H.sapiens (pooled)	14.4	0.29	1.7	11.5	18.9	11.4	33
Romano-British	14.0	0.36	1.6	11.5	18.6	11.5	20
Aust.Aborigines	15.2	0.41	1.5	13.2	18.9	9.8	13
$M\frac{}{1}$ d							
Gorilla	19.7	0.37	2.3	16.1	27.8	11.8	40
Pan	14.2	0.23	1.3	11.9	16.4	9.1	31
Pongo	20.3	0.50	2.9	14.0	26.8	14.4	34
H.sapiens (pooled)	13.8	0.24	1.4	11.0	18.1	10.1	33
Romano-British	13.4	0.28	1.2	11.0	16.5	9.3	20
Aust.Aborigines	14.4	0.39	1.4	13.0	18.1	9.8	13
$M\frac{}{2}$ m							
Gorilla	19.5	0.36	2.3	15.6	26.6	11.7	40
Pan	13.1	0.26	1.4	10.0	15.8	10.8	31
Pongo	20.5	0.53	2.9	15.0	26.7	14.4	31
H.sapiens (pooled)	14.0	0.32	1.8	10.8	18.0	13.0	33
Romano-British	13.2	0.35	1.5	10.8	16.0	11.5	19
Aust.Aborigines	15.1	0.45	1.7	12.6	18.0	11.2	14

D(iii): Actual root height

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$M_{\bar{2}}$ d							
Gorilla	18.8	0.39	2.4	15.6	25.9	12.8	39
Pan	12.9	0.30	1.7	9.5	17.1	13.2	31
Pongo	19.9	0.63	3.3	14.6	27.7	16.7	28
H.sapiens (pooled)	13.4	0.31	1.8	10.1	17.2	13.1	33
Romano-British	12.6	0.33	1.5	10.1	15.6	11.5	19
Aust.Aborigines	14.4	0.44	1.7	12.6	17.2	11.5	14
$M_{\bar{3}}$ m							
Gorilla	16.8	0.38	2.3	12.7	24.4	13.9	37
Pan	10.6	0.24	1.3	8.3	13.3	12.7	31
Pongo	17.7	0.63	2.8	13.0	22.2	15.9	20
H.sapiens (pooled)	12.8	0.35	1.8	10.6	17.2	14.2	27
Romano-British	12.3	0.42	1.6	10.6	15.1	13.2	15
Aust.Aborigines	13.4	0.56	1.9	11.2	17.2	14.3	12
$M_{\bar{3}}$ d							
Gorilla	14.5	0.41	2.3	10.8	20.3	15.9	32
Pan	10.0	0.27	1.5	7.8	14.3	14.7	29
Pongo	16.2	0.68	3.0	11.4	22.0	18.4	19
H.sapiens (pooled)	11.7	0.30	1.5	9.5	15.1	13.1	27
Romano-British	11.1	0.33	1.3	9.5	13.6	11.5	15
Aust.Aborigines	12.5	0.45	1.5	10.9	15.1	12.3	12
$I^{\underline{1}}$							
Gorilla	22.7	0.55	3.1	17.7	31.5	13.5	31
Pan	19.3	0.40	2.1	13.5	23.7	10.8	28
Pongo	21.0	0.44	2.4	15.8	28.2	11.3	29
H.sapiens(pooled)	12.8	0.30	1.5	9.8	16.1	11.8	25
Romano-British	12.5	0.28	1.2	9.8	14.5	9.8	19
Aust.Aborigines	14.0	0.77	1.9	11.5	16.1	13.4	6
$I^{\underline{2}}$							
Gorilla	22.4	0.57	2.9	16.4	28.5	12.7	25
Pan	17.6	0.44	2.1	13.9	22.4	12.1	24
Pongo	20.6	0.50	2.7	15.4	27.5	13.2	30
H.sapiens (pooled)	13.3	0.41	2.2	10.7	21.2	16.8	29
Romano-British	12.2	0.20	0.8	10.7	13.5	6.9	17
Aust.Aborigines	14.8	0.77	2.7	11.1	21.2	18.1	12

D(iii): Actual root height

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$3RP^3$ 1							
Gorilla	19.3	0.47	2.9	12.5	27.8	15.1	39
Pan	13.8	0.30	1.5	10.8	16.9	11.2	27
Pongo	19.7	0.47	2.3	16.1	23.8	11.7	24
$3RP^3$ mb							
Gorilla	22.6	0.67	4.2	15.9	33.0	18.6	39
Pan	14.4	0.47	2.5	9.0	18.8	17.0	27
Pongo	21.3	0.59	2.9	15.8	27.4	13.5	24
$3RP^3$ db							
Gorilla	18.2	0.59	3.7	12.9	25.9	20.1	39
Pan	12.1	0.35	1.8	8.5	16.7	15.0	27
Pongo	18.1	0.52	2.6	13.7	22.9	14.2	24
$2RP^3$ 1							
Pan	13.1	–	–	12.6	13.6	–	3
Pongo	18.8	–	–	17.2	20.4	–	2
H.sapiens (pooled)	13.2	0.62	1.4	11.1	14.9	10.5	5
Romano-British	12.7	–	–	11.1	13.8	–	3
Aust.Aborigines	14.1	–	–	13.2	14.9	–	2
$2RP^3$ b							
Pan	14.4	–	–	13.2	15.1	–	3
Pongo	21.7	–	–	20.2	23.2	–	2
H.sapiens (pooled)	14.2	0.78	1.8	12.2	16.6	12.3	5
Romano-British	13.1	–	–	12.2	14.0	–	3
Aust.Aborigines	15.9	–	–	15.2	16.6	–	2
$1RP^3$							
H.sapiens (pooled)	15.9	0.55	2.8	10.8	23.1	17.5	26
Romano-British	14.4	0.48	1.9	10.8	18.6	13.0	15
Aust.Aborigines	18.0	0.75	2.5	15.0	23.1	13.8	11
$3RP^4$ 1							
Gorilla	18.1	0.35	2.2	13.3	23.3	12.3	40
Pan	12.9	0.78	1.8	10.1	14.8	13.5	5
Pongo	18.8	0.51	2.7	14.0	25.9	14.2	27
$3RP^4$ mb							
Gorilla	18.7	0.59	3.7	12.9	27.1	19.9	40
Pan	12.4	0.93	2.1	10.0	15.2	16.7	5
Pongo	19.2	0.67	3.5	13.9	26.9	18.0	27

D(iii): Actual root height

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$3RP^{\underline{4}}$ db							
Gorilla	17.3	0.48	3.0	13.3	25.7	17.4	40
Pan	12.1	0.76	1.7	10.1	14.3	14.1	5
Pongo	17.6	0.57	2.9	13.4	26.6	16.7	27
$2RP^{\underline{4}}$ l							
Pan	13.2	0.34	1.7	9.8	15.7	13.0	25
Pongo	17.2	–	–	16.0	18.3	–	2
$2RP^{\underline{4}}$ b							
Pan	14.4	0.48	2.4	10.2	18.8	16.7	25
Pongo	18.6	–	–	18.2	19.0	–	2
$1RP^{\underline{4}}$							
H.sapiens (pooled)	16.0	0.44	2.5	11.8	23.7	15.7	32
Romano-British	14.9	0.42	1.8	11.8	18.8	12.3	19
Aust.Aborigines	17.7	0.69	2.5	15.1	23.7	14.0	13
$M^{\underline{1}}$ l							
Gorilla	18.4	0.30	1.9	14.5	22.2	10.2	40
Pan	13.0	0.30	1.7	10.0	16.2	12.8	31
Pongo	16.4	0.34	1.9	13.1	20.1	11.6	32
H.sapiens (pooled)	13.3	0.27	1.5	10.9	16.4	11.2	31
Romano-British	12.9	0.21	0.9	11.4	14.5	7.0	18
Aust.Aborigines	14.0	0.53	1.9	10.9	16.4	13.6	13
$M^{\underline{1}}$ mb							
Gorilla	15.8	0.41	2.6	11.4	23.6	16.5	40
Pan	11.2	0.34	1.9	7.8	15.2	17.0	31
Pongo	16.6	0.47	2.7	12.5	22.6	16.2	32
H.sapiens (pooled)	12.7	0.27	1.5	10.0	15.5	11.7	31
Romano-British	12.3	0.34	1.4	10.0	15.5	11.7	18
Aust.Aborigines	13.3	0.38	1.4	11.1	15.1	10.3	13
$M^{\underline{1}}$ db							
Gorilla	16.8	0.40	2.6	11.0	23.1	15.2	40
Pan	11.6	0.36	2.0	8.2	15.7	17.4	31
Pongo	16.0	0.41	2.3	12.4	19.5	14.6	32
H.sapiens (pooled)	12.2	0.28	1.6	8.9	15.2	12.8	31
Romano-British	11.9	0.37	1.6	8.9	14.6	13.4	18
Aust.Aborigines	12.7	0.40	1.5	10.5	15.2	11.4	13

D(iii): Actual root height

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
M- 1							
Gorilla	17.4	0.30	1.8	13.5	21.7	10.5	36
Pan	12.2	0.28	1.5	8.9	14.4	12.4	30
Pongo	16.1	0.49	2.6	9.5	22.0	16.4	29
H.sapiens (pooled)	13.3	0.31	1.6	11.3	17.6	12.3	28
Romano-British	12.8	0.33	1.2	11.3	15.5	9.6	14
Aust.Aborigines	13.8	0.50	1.9	11.5	17.6	13.7	14
M^2 mb							
Gorilla	16.8	0.46	2.8	11.8	23.5	16.6	36
Pan	11.5	0.36	2.0	8.0	15.5	17.0	30
Pongo	16.0	0.50	2.7	11.0	20.9	16.7	29
H.sapiens (pooled)	13.2	0.27	1.4	11.0	17.2	10.6	28
Romano-British	12.3	0.26	1.0	11.0	14.1	8.1	14
Aust.Aborigines	14.1	0.29	1.1	12.9	17.2	7.8	14
M^2 db							
Gorilla	16.9	0.50	3.0	12.9	26.2	17.6	36
Pan	11.2	0.36	3.0	6.8	14.9	17.7	30
Pongo	16.0	0.50	2.7	11.2	21.6	16.9	29
H.sapiens (pooled)	12.8	0.30	1.6	10.0	17.4	12.4	28
Romano-British	11.9	0.23	0.8	10.0	13.0	7.1	14
Aust.Aborigines	13.6	0.46	1.7	11.8	17.4	12.6	14
M^3 1							
Gorilla	16.1	0.34	2.1	12.8	20.9	12.9	37
Pan	11.3	0.22	1.2	8.5	13.4	10.7	30
Pongo	15.0	0.47	2.3	11.2	18.5	15.4	24
H.sapiens (pooled)	12.8	0.56	1.9	10.4	16.3	15.2	12
Romano-British	11.3	–	–	10.4	11.9	–	4
Aust.Aborigines	13.5	0.69	2.0	11.0	16.3	14.4	8
M^3 mb							
Gorilla	15.9	0.49	3.0	11.8	26.8	18.7	37
Pan	10.7	0.28	1.6	8.0	13.6	14.6	30
Pongo	14.3	0.48	2.4	10.4	18.8	16.5	24
H.sapiens (pooled)	13.3	0.81	2.8	10.2	19.2	20.9	12
Romano-British	12.5	–	–	10.2	16.7	–	4
Aust.Aborigines	13.7	1.01	2.9	10.5	19.2	20.8	8

D(iii): Actual root height

-	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
M_3^2 db							
Gorilla	15.2	0.48	2.9	10.8	21.5	19.1	37
Pan	10.4	0.29	1.6	6.5	13.4	15.3	30
Pongo	14.1	0.51	2.5	10.6	20.3	17.8	24
H.sapiens (pooled)	12.8	0.69	2.4	9.6	18.0	18.7	12
Romano-British	11.8	–	–	9.6	14.8	–	4
Aust.Aborigines	13.4	0.87	2.5	10.6	18.0	18.5	8

D(iv): Projected root height

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$I_{\bar{1}}$							
Gorilla	20.8	0.50	2.7	17.3	28.8	12.7	28
Pan	16.5	0.33	1.7	12.6	19.0	10.3	26
Pongo	21.1	0.45	2.5	17.1	27.4	11.8	31
H.sapiens (pooled)	12.9	0.35	1.8	10.2	17.1	13.6	25
Romano-British	12.4	0.35	1.4	10.2	15.3	11.5	17
Aust.Aborigines	14.2	0.66	1.9	11.7	17.1	13.1	8
$I_{\bar{2}}$							
Gorilla	22.0	0.39	2.4	17.2	27.8	10.7	36
Pan	17.0	0.44	2.3	11.6	22.0	13.4	26
Pongo	21.8	0.43	2.4	17.6	28.8	11.0	31
H.sapiens (pooled)	14.3	0.33	1.8	10.5	18.8	12.6	30
Romano-British	14.2	0.32	1.4	12.3	18.8	10.1	20
Aust.Aborigines	14.5	0.78	2.5	10.5	18.7	16.9	10
$2RP_{\bar{3}}$ m							
Gorilla	22.3	0.45	2.8	18.0	28.5	12.6	39
Pan	17.9	0.52	2.5	12.2	21.8	13.7	22
Pongo	24.9	0.64	3.5	19.0	32.5	14.0	30
Aust.Aborigines	16.1	–	–	–	–	–	1
$2RP_{\bar{3}}$ d							
Gorilla	21.9	0.51	3.1	17.2	31.6	14.3	39
Pan	17.4	0.48	2.3	12.2	20.8	12.9	22
Pongo	23.1	0.70	3.9	16.3	32.8	16.7	30
Aust.Aborigines	15.8	–	–	–	–	–	1
$1RP_{\bar{3}}$							
Pan	17.0	0.49	1.5	15.5	19.4	8.6	9
Pongo	24.8	–	–	–	–	–	1
H.sapiens (pooled)	15.6	0.33	1.8	12.6	20.1	11.8	31
Romano-British	15.0	0.32	1.4	12.6	18.4	9.6	20
Aust.Aborigines	16.6	0.62	2.1	13.0	20.1	12.4	11
$2RP_{\bar{4}}$ m							
Gorilla	20.1	0.32	2.0	15.3	24.1	9.6	37
Pan	17.0	0.41	2.3	12.3	23.3	13.3	31
Pongo	22.6	0.65	3.7	14.8	31.3	16.1	32

D(iv): Projected root height

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$2RP_{\bar{4}}$ d							
Gorilla	20.6	0.30	1.8	17.3	24.8	8.9	38
Pan	16.5	0.32	1.8	12.6	20.1	10.7	31
Pongo	21.6	0.59	3.3	14.8	31.8	15.4	32
$1RP_{\bar{4}}$							
H.sapiens (pooled)	15.8	0.36	2.1	12.4	21.2	13.0	33
Romano-British	15.3	0.45	2.0	12.4	19.2	13.2	20
Aust.Aborigines	16.6	0.54	2.0	13.6	21.2	11.8	13
$M_{\bar{1}}$ m							
Gorilla	18.0	0.37	2.3	13.0	23.9	13.0	40
Pan	13.1	0.26	1.5	10.7	15.9	11.2	31
Pongo	20.2	0.46	2.7	14.4	25.3	13.4	34
H.sapiens (pooled)	14.2	0.28	1.6	11.3	18.5	11.4	33
Romano-British	13.8	0.36	1.6	11.3	18.5	11.8	20
Aust.Aborigines	14.9	0.40	1.4	12.6	18.3	9.7	13
$M_{\bar{1}}$ d							
Gorilla	18.5	0.38	2.4	14.3	27.1	12.8	40
Pan	13.9	0.22	1.2	11.6	15.9	8.9	31
Pongo	19.6	0.48	2.8	13.1	26.0	14.2	34
H.sapiens (pooled)	13.4	0.24	1.4	10.6	17.5	10.2	33
Romano-British	13.0	0.28	1.2	10.6	16.1	9.6	20
Aust.Aborigines	14.0	0.37	1.3	12.6	17.5	9.5	13
$M_{\bar{2}}$ m							
Gorilla	19.3	0.37	2.3	15.3	26.6	12.0	40
Pan	13.0	0.25	1.4	9.8	15.5	10.9	31
Pongo	20.3	0.53	2.9	15.0	26.3	14.4	31
H.sapiens (pooled)	13.7	0.30	1.7	10.6	17.5	12.5	33
Romano-British	13.0	0.32	1.4	10.6	15.4	10.9	19
Aust.Aborigines	14.7	0.43	1.6	12.3	17.5	10.9	14
$M_{\bar{2}}$ d							
Gorilla	18.0	0.40	2.5	14.4	25.4	13.7	39
Pan	12.6	0.30	1.6	9.2	16.6	13.0	31
Pongo	19.4	0.63	3.3	14.0	27.4	17.2	28
H.sapiens (pooled)	13.1	0.31	1.8	9.7	16.8	13.5	33
Romano-British	12.4	0.34	1.5	9.7	15.3	11.8	19
Aust.Aborigines	14.2	0.44	1.6	12.4	16.8	11.6	14

D(iv): Projected root height

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$M_{\bar{3}}$ m							
Gorilla	16.6	0.39	2.4	12.7	24.4	14.3	37
Pan	10.5	0.24	1.3	8.3	13.3	12.7	31
Pongo	17.5	0.62	2.8	13.0	22.1	15.8	20
H.sapiens (pooled)	12.4	0.35	1.8	10.2	16.7	14.8	27
Romano-British	11.8	0.41	1.6	10.2	14.9	13.4	15
Aust.Aborigines	13.2	0.54	1.9	11.2	16.7	14.2	12
$M_{\bar{3}}$ d							
Gorilla	13.4	0.40	2.3	9.9	18.8	16.9	32
Pan	9.7	0.26	1.4	7.5	13.7	14.6	29
Pongo	15.6	0.69	3.0	11.0	21.6	19.4	19
H.sapiens (pooled)	11.5	0.30	1.5	9.2	14.7	13.3	27
Romano-British	10.8	0.32	1.3	9.2	13.5	11.5	15
Aust.Aborigines	12.4	0.42	1.5	10.7	14.7	11.8	12
I_{-}^{1}							
Gorilla	22.5	0.56	3.1	17.2	31.3	13.8	31
Pan	19.2	0.40	2.1	13.4	23.7	10.9	28
Pongo	20.9	0.45	2.4	15.7	28.3	11.5	29
H.sapiens (pooled)	12.8	0.31	1.5	9.8	16.1	12.0	25
Romano-British	12.4	0.28	1.2	9.8	14.4	9.9	19
Aust.Aborigines	14.0	0.77	1.9	11.5	16.1	13.5	6
I_{-}^{2}							
Gorilla	22.1	0.56	2.8	16.5	28.2	12.6	25
Pan	17.5	0.44	2.2	13.9	22.3	12.3	24
Pongo	20.6	0.50	2.7	15.3	27.4	13.2	30
H.sapiens (pooled)	13.2	0.41	2.2	10.6	21.1	16.9	29
Romano-British	12.1	0.21	0.9	10.6	13.5	7.1	17
Aust.Aborigines	14.8	0.77	2.7	11.1	21.1	18.0	12
$3RP^{\bar{3}}$ l							
Gorilla	19.1	0.47	2.9	12.5	27.8	15.2	39
Pan	13.7	0.30	1.5	10.7	16.6	11.2	27
Pongo	19.4	0.45	2.2	15.8	23.5	11.3	24
$3RP^{\bar{3}}$ mb							
Gorilla	22.5	0.68	4.2	15.7	33.0	18.8	39
Pan	14.3	0.48	2.5	8.9	18.8	17.2	27
Pongo	21.2	0.57	2.8	15.8	26.4	13.2	24

D(iv): Projected root height

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$3RP^{3}$ db							
Gorilla	18.0	0.60	3.7	12.3	25.8	20.7	39
Pan	11.9	0.36	1.9	8.1	16.5	15.7	27
Pongo	17.8	0.54	2.7	13.3	22.4	14.8	24
$2RP^{3}$ 1							
Pan	13.0	–	–	12.4	13.5	–	3
Pongo	18.5	–	–	16.5	20.4	–	2
H.sapiens (pooled)	13.1	0.64	1.4	10.9	14.9	10.9	5
Romano-British	12.5	–	–	10.9	13.4	–	3
Aust.Aborigines	14.1	–	–	13.2	14.9	–	2
$2RP^{3}$ b							
Pan	14.4	–	–	13.0	15.1	–	3
Pongo	21.5	–	–	19.7	23.2	–	2
H.sapiens (pooled)	14.0	0.75	1.7	12.2	16.3	11.9	5
Romano-British	12.9	–	–	12.2	13.4	–	3
Aust.Aborigines	15.7	–	–	15.1	16.3	–	2
$1RP^{3}$							
H.sapiens (pooled)	15.9	0.54	2.7	10.8	23.1	17.3	26
Romano-British	14.4	0.47	1.8	10.8	18.6	12.7	15
Aust.Aborigines	17.9	0.75	2.5	15.0	23.1	13.8	11
$3RP^{4}$ 1							
Gorilla	17.9	0.35	2.2	13.3	23.3	12.2	40
Pan	12.9	0.78	1.7	10.1	14.8	13.5	5
Pongo	18.6	0.50	2.6	13.7	25.2	14.1	27
$3RP^{4}$ mb							
Gorilla	18.6	0.58	3.7	12.8	26.5	19.6	40
Pan	12.4	0.92	2.1	10.0	15.2	16.6	5
Pongo	19.2	0.66	3.5	13.7	26.6	18.0	27
$3RP^{4}$ db							
Gorilla	17.1	0.46	2.9	12.7	25.2	17.0	40
Pan	12.1	0.76	1.7	10.1	14.3	14.1	5
Pongo	17.4	0.57	2.9	13.2	26.4	16.9	27
$2RP^{4}$ 1							
Pan	13.1	0.34	1.7	9.7	15.6	13.1	25
Pongo	16.9	–	–	15.6	18.2	–	2

D(iv): Projected root height

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$2RP^{4}$ b							
Pan	14.4	0.48	2.4	10.2	18.8	16.6	25
Pongo	17.9	–	–	17.8	18.0	–	2
$1RP^{4}$							
H.sapiens (pooled)	16.0	0.44	2.5	11.8	23.7	15.7	32
Romano-British	14.8	0.42	1.8	11.8	18.8	12.3	19
Aust. Aborigines	17.6	0.69	2.5	15.1	23.7	14.0	13
M^{1} l							
Gorilla	18.2	0.29	1.8	14.4	21.4	9.9	40
Pan	12.9	0.29	1.6	10.0	16.2	12.7	31
Pongo	16.2	0.34	1.9	12.9	20.0	11.8	32
H.sapiens (pooled)	13.2	0.28	1.6	10.5	16.4	11.8	31
Romano-British	12.7	0.23	1.0	11.2	14.5	7.6	18
Aust.Aborigines	13.9	0.55	2.0	10.5	16.4	14.2	13
M^{1} mb							
Gorilla	15.6	0.40	2.5	11.2	23.2	16.2	40
Pan	11.1	0.33	1.9	7.8	15.0	16.7	31
Pongo	16.1	0.44	2.5	12.2	21.3	15.5	32
H.sapiens (pooled)	12.6	0.27	1.5	9.6	15.5	11.8	31
Romano-British	12.2	0.35	1.5	9.6	15.5	12.1	18
Aust.Aborigines	13.2	0.38	1.4	10.9	15.1	10.3	13
M^{1} db							
Gorilla	16.2	0.38	2.4	10.7	21.4	14.6	40
Pan	11.4	0.37	2.1	8.2	15.5	17.9	31
Pongo	15.5	0.42	2.4	11.5	18.9	15.1	32
H.sapiens (pooled)	12.0	0.29	1.6	8.6	15.0	13.6	31
Romano-British	11.7	0.39	1.7	8.6	14.6	14.3	18
Aust.Aborigines	12.5	0.42	1.5	10.2	15.0	12.2	13
M^{2} l							
Gorilla	17.3	0.31	1.9	13.0	21.7	10.9	36
Pan	12.1	0.27	1.5	8.9	14.3	12.3	30
Pongo	15.8	0.49	2.6	9.5	21.7	16.6	29
H.sapiens (pooled)	13.0	0.32	1.7	10.8	17.5	12.9	28
Romano-British	12.6	0.36	1.3	10.8	15.5	10.6	14
Aust.Aborigines	13.5	0.52	1.9	11.2	17.5	14.3	14

D(iv): Projected root height

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
M^2 mb							
Gorilla	16.7	0.46	2.8	11.8	22.9	16.5	36
Pan	11.4	0.35	1.9	8.0	15.5	16.7	30
Pongo	15.9	0.48	2.6	11.0	20.9	16.4	29
H.sapiens (pooled)	13.0	0.27	1.4	10.9	17.2	11.0	28
Romano-British	12.1	0.26	1.0	10.9	13.9	7.9	14
Aust.Aborigines	13.9	0.33	1.2	12.6	17.2	8.8	14
M^2 db							
Gorilla	16.8	0.49	3.0	12.7	26.2	17.6	36
Pan	11.0	0.36	2.0	6.5	14.6	18.1	30
Pongo	15.8	0.50	2.7	11.2	21.3	17.0	29
H.sapiens (pooled)	12.5	0.31	1.6	9.2	17.1	13.1	28
Romano-British	11.6	0.25	1.0	9.2	12.9	8.1	14
Aust.Aborigines	13.4	0.47	1.8	11.5	17.1	13.2	14
M^3 l							
Gorilla	15.5	0.33	2.0	12.5	20.8	13.0	37
Pan	10.9	0.22	1.2	8.3	13.2	10.9	30
Pongo	14.2	0.45	2.2	10.7	17.9	15.7	24
H.sapiens (pooled)	12.4	0.50	1.7	10.4	15.2	13.9	12
Romano-British	11.1	–	–	10.4	11.8	–	4
Aust.Aborigines	13.1	0.60	1.7	11.0	15.2	12.9	8
M^3 mb							
Gorilla	15.7	0.49	3.0	11.4	26.5	18.9	37
Pan	10.6	0.29	1.6	7.8	13.5	14.8	30
Pongo	14.2	0.48	2.3	10.2	18.6	16.4	24
H.sapiens (pooled)	12.9	0.72	2.5	9.2	17.9	19.3	12
Romano-British	11.9	–	–	9.2	15.5	–	4
Aust.Aborigines	13.3	0.86	2.4	10.5	17.9	18.3	8
M^3 db							
Gorilla	14.8	0.47	2.9	9.5	20.8	19.2	37
Pan	10.1	0.30	1.7	5.9	13.4	16.4	30
Pongo	13.3	0.48	2.4	9.9	18.9	17.7	24
H.sapiens (pooled)	12.4	0.64	2.2	9.3	17.5	17.8	12
Romano-British	11.5	–	–	9.3	13.8	–	4
Aust.Aborigines	12.9	0.83	2.3	10.4	17.5	18.1	8

D(v): Root mesiodistal diameter

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$C_{\overline{1}}$							
Gorilla	11.1	0.54	3.0	7.1	19.2	26.8	30
Pan	8.6	0.30	1.5	5.7	10.6	17.8	27
Pongo	8.8	0.47	1.8	6.2	12.1	10.6	15
H.sapiens (pooled)	5.4	0.17	1.0	3.4	7.4	17.8	31
Romano-British	5.2	0.24	1.1	3.4	6.9	20.4	19
Aust.Aborigines	5.8	0.19	0.7	4.5	7.4	11.5	12
$2RP_{\overline{3}}$ m							
Gorilla	5.8	0.12	0.8	4.2	8.0	13.4	39
Pan	3.9	0.13	0.6	2.8	5.1	15.7	22
Pongo	5.0	0.14	0.8	3.9	6.7	15.6	30
Aust.Aborigines	1.8	–	–	–	–	–	1
$2RP_{\overline{3}}$ d							
Gorilla	5.4	0.13	0.8	4.1	7.5	15.3	39
Pan	3.6	0.10	0.5	2.8	4.9	13.5	22
Pongo	4.6	0.13	0.7	3.2	5.9	15.5	30
Aust.Aborigines	2.7	–	–	–	–	–	1
$1RP_{\overline{3}}$							
Pan	6.1	0.25	0.8	4.9	7.6	12.4	9
Pongo	6.0	–	–	–	–	–	1
H.sapiens (pooled)	3.5	0.11	0.6	2.5	4.8	17.5	31
Romano-British	3.3	0.09	0.4	2.5	3.8	11.9	20
Aust.Aborigines	3.9	0.22	0.7	2.6	4.8	18.8	11
$2RP_{\overline{4}}$ m							
Gorilla	3.9	0.06	0.4	3.1	4.6	8.9	37
Pan	3.2	0.08	0.4	2.5	4.0	13.0	30
Pongo	3.8	0.09	0.5	3.1	4.8	13.0	32
$2RP_{\overline{4}}$ d							
Gorilla	4.9	0.08	0.5	4.0	5.9	10.1	38
Pan	3.7	0.09	0.5	2.4	4.7	12.9	30
Pongo	4.3	0.09	0.5	3.2	5.4	12.3	32
$1RP_{\overline{4}}$							
H.sapiens (pooled)	3.7	0.08	0.5	3.0	4.7	12.5	33
Romano-British	3.6	0.07	0.3	3.2	4.2	8.8	20
Aust.Aborigines	3.8	0.17	0.6	3.0	4.7	16.5	13

D(v): Root mesiodistal diameter

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$M_{\bar{1}}$ m							
Gorilla	4.6	0.13	0.8	3.5	6.9	17.3	40
Pan	3.8	0.08	0.4	2.9	4.8	11.2	31
Pongo	3.9	0.10	0.6	2.8	5.6	15.0	34
H.sapiens (pooled)	3.8	0.12	0.7	2.6	5.5	17.6	33
Romano-British	3.7	0.18	0.8	2.6	5.5	21.9	20
Aust.Aborigines	3.8	0.09	0.3	3.2	4.2	8.5	13
$M_{\bar{1}}$ d							
Gorilla	5.8	0.11	0.7	4.2	7.4	11.5	40
Pan	3.9	0.07	0.4	3.2	4.7	10.1	31
Pongo	4.1	0.10	0.6	3.1	5.2	14.3	34
H.sapiens (pooled)	3.4	0.09	0.5	2.4	4.8	14.3	33
Romano-British	3.3	0.09	0.4	2.4	4.0	12.5	20
Aust.Aborigines	3.5	0.16	0.6	2.7	4.8	16.5	13
$M_{\bar{2}}$ m							
Gorilla	5.1	0.12	0.8	3.8	7.5	15.0	40
Pan	3.8	0.07	0.4	3.0	4.7	9.8	31
Pongo	4.3	0.13	0.7	3.1	6.2	17.1	31
H.sapiens (pooled)	3.3	0.07	0.4	2.7	4.3	12.7	33
Romano-British	3.2	0.09	0.4	2.7	4.2	12.3	19
Aust.Aborigines	3.3	0.12	0.4	2.8	4.3	13.4	14
$M_{\bar{2}}$ d							
Gorilla	6.2	0.12	0.8	4.9	7.9	12.4	39
Pan	3.9	0.08	0.4	3.0	4.9	10.9	31
Pongo	4.8	0.11	0.6	3.4	6.1	12.4	28
H.sapiens (pooled)	3.6	0.09	0.5	2.9	5.3	13.9	
Romano-British	3.5	0.09	0.4	3.0	4.4	10.9	19
Aust.Aborigines	3.7	0.17	0.6	2.9	5.3	16.9	14
$M_{\bar{3}}$ m							
Gorilla	4.9	0.10	0.6	3.5	6.4	12.0	37
Pan	3.9	0.10	0.6	2.9	5.3	14.3	31
Pongo	4.2	0.10	0.5	3.4	5.0	10.8	20
H.sapiens (pooled)	3.6	0.09	0.5	2.5	4.5	13.6	27
Romano-British	3.5	0.13	0.5	2.5	4.4	14.7	15
Aust.Aborigines	3.8	0.12	0.4	3.1	4.5	11.3	12

D(v): Root mesiodistal diameter

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$M_{\bar{3}}$ d							
Gorilla	6.0	0.14	0.8	4.7	8.0	13.1	32
Pan	4.0	0.10	0.5	3.1	5.2	13.1	29
Pongo	4.7	0.18	0.8	3.4	6.4	16.8	19
H.sapiens (pooled)	3.6	0.13	0.7	2.3	5.1	18.0	27
Romano-British	3.4	0.16	0.6	2.3	4.5	18.2	15
Aust,Aborigines	3.9	0.17	0.6	3.1	5.1	15.1	12
$3RP^{\underline{3}}$ l							
Gorilla	7.3	0.18	1.1	5.6	10.6	15.1	39
Pan	4.2	0.12	0.6	2.7	5.3	15.1	27
Pongo	5.0	0.14	0.7	4.1	6.4	13.3	24
$3RP^{\underline{3}}$ mb							
Gorilla	5.4	0.17	1.1	3.8	8.4	20.2	39
Pan	3.6	0.12	0.6	2.2	4.7	17.7	27
Pongo	4.0	0.16	0.8	2.6	5.7	19.4	24
$3RP^{\underline{3}}$ db							
Gorilla	3.6	0.08	0.5	2.7	4.6	14.1	39
Pan	2.8	0.09	0.5	2.0	4.3	16.2	27
Pongo	3.0	0.08	0.4	2.3	4.0	13.6	24
$2RP^{\underline{3}}$ l							
Pan	4.0	–	–	3.4	4.9	–	3
Pongo	4.6	–	–	4.2	4.9	–	2
H.sapiens (pooled)	3.6	0.17	0.4	3.3	4.2	10.4	5
Romano-British	3.6	–	–	3.3	3.8	–	3
Aust.Aborigines	3.8	–	–	3.3	4.2	–	2
$2RP^{\underline{3}}$ b							
Pan	4.8	–	–	4.5	5.2	–	3
Pongo	4.9	–	–	4.5	5.2	–	2
H.sapiens (pooled)	3.3	0.18	0.4	2.9	3.9	11.9	5
Romano-British	3.1	–	–	2.9	3.4	–	3
Aust.Aborigines	3.7	–	–	3.4	3.9	–	2
$1RP^{\underline{3}}$							
H.sapiens (pooled)	3.6	0.09	0.5	2.9	4.4	12.7	26
Romano-British	3.4	0.11	0.4	2.9	4.0	12.3	15
Aust.Aborigines	3.9	0.10	0.3	3.4	4.4	8.1	11
$3RP^{\underline{4}}$ l							
Gorilla	7.8	0.17	1.1	6.3	10.1	13.6	40
Pan	4.3	0.40	0.9	2.8	5.2	20.8	5
Pongo	5.3	0.14	0.8	3.8	6.9	14.2	27

D(v): Root mesiodistal diameter

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$3RP^{\underline{4}}$ mb							
Gorilla	3.9	0.11	0.7	2.7	5.6	18.0	40
Pan	2.5	0.15	0.3	2.0	2.9	13.3	5
Pongo	3.2	0.08	0.4	2.6	4.1	13.0	27
$3RP^{\underline{4}}$ db							
Gorilla	3.5	0.07	0.4	2.6	4.8	12.6	40
Pan	2.6	0.09	0.2	2.3	2.8	7.3	5
Pongo	3.4	0.09	0.4	2.6	4.3	13.2	27
$2RP^{\underline{4}}$ l							
Pan	4.3	0.14	0.7	3.3	6.3	15.8	25
Pongo	4.7	–	–	4.1	5.3	–	2
$2RP^{\underline{4}}$ b							
Pan	3.9	0.12	0.6	2.8	5.0	15.8	25
Pongo	4.1	–	–	4.1	4.1	–	2
$1RP^{\underline{4}}$							
H.sapiens (pooled)	3.6	0.08	0.5	2.6	4.6	12.5	32
Romano-British	3.4	0.09	0.4	2.6	4.1	11.7	19
Aust.Aborigines	3.8	0.12	0.4	3.1	4.6	11.1	13
$M^{\underline{1}}$ l							
Gorilla	9.5	0.19	1.2	7.5	12.1	12.6	40
Pan	5.1	0.12	0.7	3.2	6.1	13.2	31
Pongo	7.0	0.12	0.7	5.4	8.8	9.7	32
H.sapiens (pooled)	4.8	0.12	0.7	3.5	6.1	14.1	31
Romano-British	4.6	0.14	0.6	3.5	5.5	12.6	18
Aust.Aborigines	5.2	0.19	0.7	4.0	6.1	13.5	13
$M^{\underline{1}}$ mb							
Gorilla	4.3	0.10	0.6	2.9	5.8	14.9	40
Pan	3.2	0.08	0.4	2.3	4.0	13.3	31
Pongo	3.6	0.08	0.5	2.7	4.5	12.6	32
H.sapiens (pooled)	3.2	0.09	0.5	2.4	4.6	14.7	31
Romano-British	3.1	0.08	0.3	2.4	3.8	10.8	18
Aust.Aborigines	3.4	0.16	0.6	2.6	4.6	17.5	13
$M^{\underline{1}}$ db							
Gorilla	4.6	0.10	0.7	3.6	6.3	14.3	40
Pan	3.1	0.08	0.4	2.4	4.1	13.4	31
Pongo	3.5	0.10	0.6	2.6	4.9	15.8	32
H.sapiens (pooled)	3.0	0.07	0.4	2.1	3.6	13.3	31
Romano-British	2.9	0.09	0.4	2.1	3.3	12.7	18
Aust.Aborigines	3.1	0.11	0.4	2.4	3.6	13.2	13

D(v): Root mesiodistal diameter

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
M^2 l							
Gorilla	11.0	0.26	1.6	7.8	14.2	14.4	36
Pan	5.3	0.15	0.8	4.1	6.9	15.0	30
Pongo	7.3	0.15	0.8	5.6	9.0	11.3	29
H.sapiens (pooled)	4.5	0.13	0.7	3.3	6.0	15.2	28
Romano-British	4.2	0.17	0.7	3.3	6.0	15.6	14
Aust.Aborigines	4.8	0.16	0.6	3.6	5.8	12.4	14
M^2 mb							
Gorilla	4.5	0.12	0.7	3.4	6.7	16.2	36
Pan	3.2	0.08	0.5	2.4	4.0	14.2	30
Pongo	3.9	0.07	0.4	3.0	4.5	9.4	29
H.sapiens (pooled)	3.1	0.08	0.4	2.2	3.8	13.4	28
Romano-British	2.9	0.12	0.5	2.2	3.8	15.6	14
Aust.Aborigines	3.2	0.09	0.3	2.8	3.8	10.2	14
M^2 db							
Gorilla	4.9	0.13	0.8	3.5	6.7	15.9	36
Pan	2.9	0.07	0.4	2.1	3.5	12.4	30
Pongo	3.7	0.09	0.5	3.0	4.9	13.0	29
H.sapiens (pooled)	3.0	0.09	0.5	2.2	3.8	15.1	28
Romano-British	2.9	0.12	0.4	2.2	3.6	14.7	14
Aust.Aborigines	3.0	0.13	0.5	2.2	3.8	15.7	14
M^3 l							
Gorilla	8.9	0.23	1.4	6.4	11.1	15.8	37
Pan	4.6	0.11	0.6	3.4	6.1	12.7	30
Pongo	6.9	0.17	0.8	5.1	8.4	12.1	24
H.sapiens (pooled)	4.4	0.22	0.8	2.9	5.8	16.9	12
Romano-British	4.2	–	–	3.5	4.5	–	4
Aust.Aborigines	4.5	0.30	0.9	2.9	5.8	19.0	8
M^3 mb							
Gorilla	4.3	0.10	0.6	2.7	5.5	13.9	37
Pan	3.0	0.08	0.5	2.2	4.3	15.3	30
Pongo	3.6	0.09	0.5	2.7	4.7	12.8	24
H.sapiens (pooled)	3.2	0.17	0.6	2.5	4.4	18.7	12
Romano-British	2.8	–	–	2.5	2.9	–	4
Aust.Aborigines	3.4	0.22	0.6	2.7	4.4	18.2	8

D(v): Root mesiodistal diameter

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
M_2^3 db							
Gorilla	4.2	0.14	0.8	2.9	6.0	20.0	37
Pan	2.8	0.09	0.5	2.1	4.1	17.7	30
Pongo	3.8	0.13	0.6	2.4	4.9	16.9	24
H.sapiens (pooled)	2.8	0.12	0.4	2.3	3.6	14.7	12
Romano-British	2.5	–	–	2.3	2.8	–	4
Aust.Aborigines	2.9	0.14	0.4	2.4	3.6	13.7	8

D(vi): Height of bifurcation

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$2RP_{\overline{3}}$							
Gorilla	4.7	0.31	2.0	1.7	11.7	41.4	40
Pan	4.8	0.38	1.8	2.4	9.7	36.7	22
Pongo	6.3	0.34	2.0	2.5	10.6	31.3	33
H.sapiens (pooled)	7.8	–	–	–	–	–	1
$2RP_{\overline{4}}$							
Gorilla	5.9	0.19	1.2	3.2	9.3	19.8	39
Pan	5.4	0.31	1.7	2.7	12.3	32.2	31
Pongo	5.0	0.21	1.2	3.3	8.9	24.5	34
$M_{\overline{1}}$							
Gorilla	3.5	0.11	0.7	2.4	5.5	19.5	40
Pan	3.2	0.10	0.5	2.2	4.8	16.6	31
Pongo	4.2	0.14	0.8	2.8	5.8	18.9	34
H.sapiens (pooled)	4.2	0.11	0.6	3.1	5.7	14.9	33
Romano-British	4.2	0.14	0.6	3.1	5.7	15.3	20
Aust.Aborigines	4.2	0.17	0.6	3.4	5.3	14.7	13
$M_{\overline{2}}$							
Gorilla	4.2	0.13	0.8	2.6	6.1	19.3	40
Pan	3.4	0.12	0.7	1.9	5.1	20.2	31
Pongo	4.5	0.15	0.9	2.8	6.6	19.8	34
H.sapiens (pooled)	4.3	0.12	0.7	3.2	5.6	15.6	33
Romano-British	4.2	0.13	0.6	3.2	5.4	13.3	19
Aust.Aborigines	4.3	0.21	0.8	3.4	5.6	18.6	14
$M_{\overline{3}}$							
Gorilla	3.9	0.12	0.7	2.4	5.5	18.7	39
Pan	3.4	0.16	0.9	1.5	5.9	26.7	31
Pongo	4.3	0.14	0.8	2.6	5.8	18.5	34
H.sapiens (pooled)	4.5	0.17	0.9	3.0	7.3	20.1	28
Romano-British	4.2	0.19	0.7	3.0	5.6	17.9	15
Aust.Aborigines	5.0	0.26	0.9	3.7	7.3	18.6	13
$3RP^{\overline{2}}$							
Gorilla	5.0	0.27	1.7	1.6	8.0	33.4	39
Pan	4.8	0.25	1.3	2.0	7.4	27.5	27
Pongo	6.1	0.34	1.7	3.9	11.5	27.2	24

D(vi): Height of bifurcation

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$3RP^4$							
Gorilla	5.1	0.20	1.3	2.3	8.0	25.1	40
Pan	4.0	0.59	1.3	3.0	5.9	33.5	5
Pongo	5.8	0.30	1.6	3.4	9.5	26.7	27
M^1							
Gorilla	2.9	0.19	1.2	0.8	6.9	41.5	40
Pan	2.8	0.17	1.0	1.3	4.6	34.0	31
Pongo	3.9	0.20	1.1	2.2	6.5	28.7	32
H.sapiens (pooled)	4.0	0.18	1.0	2.3	5.5	24.7	31
Romano-British	3.9	0.27	1.2	2.3	5.5	29.4	18
Aust.Aborigines	4.0	0.20	0.7	2.8	5.2	17.5	13
M^2							
Gorilla	3.2	0.21	1.3	0.9	6.4	40.1	36
Pan	3.0	0.21	1.1	0.9	5.5	38.1	30
Pongo	3.8	0.19	1.0	2.4	6.7	27.0	29
H.sapiens (pooled)	4.6	0.21	1.1	2.7	7.1	23.7	28
Romano-British	4.6	0.32	1.2	2.9	7.1	25.8	14
Aust.Aborigines	4.6	0.28	1.0	2.7	6.2	22.5	14
M^3							
Gorilla	3.4	0.22	1.3	1.1	5.9	39.3	37
Pan	3.4	0.16	0.9	1.9	4.7	25.6	30
Pongo	3.5	0.27	1.3	1.6	6.5	38.1	24
H.sapiens (pooled)	4.8	0.32	1.1	3.2	6.4	23.6	12
Romano-British	4.4	–	–	3.2	6.4	–	4
Aust.Aborigines	5.0	0.35	1.0	3.5	6.4	19.9	8

D(vii): Root angulation

	$\bar{X}$	S.E.	S.D.	min	max	N
$I_{\overline{1}}$						
Gorilla	+2	0.83	4.4	-5	+14	28
Pan	+5	1.04	5.3	-6	+19	26
Pongo	+2	0.56	3.1	-3	+9	31
H.sapiens (pooled)	-1	0.76	3.8	-11	+7	25
Romano-British	-1	0.97	4.0	-11	+7	17
Aust.Aborigines	-3	1.00	2.8	-8	+1	8
$I_{\overline{2}}$						
Gorilla	+13	0.81	4.9	+4	+22	36
Pan	+12	0.84	4.3	+3	+20	26
Pongo	+11	1.03	5.7	+2	+24	31
H.sapiens (pooled)	+3	0.91	5.0	-5	+17	30
Romano-British	+2	1.14	5.1	-5	+17	20
Aust.Aborigines	+4	1.54	4.9	-5	+10	10
$2RP_{\overline{3}}$ m						
Gorilla	-6	0.79	4.9	-18	+4	39
Pan	-6	1.06	5.0	-15	+3	22
Pongo	-6	0.91	5.0	-16	+4	30
Aust.Aborigines	-8	-	-	-	-	1
$2RP_{\overline{3}}$ d						
Gorilla	+1	0.70	4.4	-8	+10	39
Pan	-5	0.72	3.4	-12	+2	22
Pongo	-6	0.81	4.4	-16	+1	30
Aust.Aborigines	-2	-	-	-	-	1
$1RP_{\overline{3}}$						
Pan	-6	2.33	7.0	-16	+1	9
Pongo	-6	-	-	-	-	1
H.sapiens (pooled)	-5	0.60	3.4	-14	+3	31
Romano-British	-4	0.64	2.9	-8	+3	20
Aust.Aborigines	-6	1.12	3.7	-14	-1	11
$2RP_{\overline{4}}$ m						
Gorilla	-2	0.62	3.8	-8	+7	37
Pan	-2	0.78	4.3	-10	+8	31
Pongo	-4	0.83	4.7	-14	+6	32

D(vii): Root angulation

	$\bar{X}$	S.E.	S.D.	min	max	N
$2RP_4^-$ d						
Gorilla	-6	0.54	3.3	-11	+2	38
Pan	-7	0.81	4.5	-16	+1	31
Pongo	-9	0.72	4.1	-17	-1	32
$1RP_4^-$						
H.sapiens (pooled)	-4	0.33	1.9	-8	-1	33
Romano-British	-3	0.38	1.7	-7	-1	20
Aust.Aborigines	-4	0.60	2.2	-8	-1	13
M_1^- m						
Gorilla	-4	0.63	4.0	-13	+4	40
Pan	-2	0.62	3.4	-7	+6	31
Pongo	-5	0.64	3.7	-13	+2	34
H.sapiens (pooled)	-4	0.78	4.5	-13	+5	33
Romano-British	-3	0.97	4.3	-10	+5	20
Aust.Aborigines	-7	0.96	3.5	-13	0	13
M_1^- d						
Gorilla	-16	0.77	4.9	-28	-8	40
Pan	-11	0.82	4.6	-24	-2	31
Pongo	-13	0.60	3.5	-19	-4	34
H.sapiens (pooled)	-12	0.53	3.1	-20	-6	33
Romano-British	-13	0.71	3.2	-20	-7	20
Aust.Aborigines	-11	0.69	2.5	-14	-6	13
M_2^- m						
Gorilla	-4	0.60	3.8	-13	+2	40
Pan	-1	0.65	3.6	-7	+7	31
Pongo	-3	0.70	3.9	-11	+4	31
H.sapiens (pooled)	-8	0.64	3.7	-17	-2	33
Romano-British	-8	0.76	3.3	-14	-3	19
Aust.Aborigines	-9	1.12	4.2	-17	-2	14
M_2^- d						
Gorilla	-15	0.69	4.3	-22	-5	39
Pan	-10	0.59	3.3	-17	-4	31
Pongo	-10	0.60	3.2	-18	-6	28
H.sapiens (pooled)	-8	0.70	4.0	-18	0	33
Romano-British	-8	0.80	3.5	-18	-5	19
Aust.Aborigines	-7	1.16	4.3	-14	0	14

D(vii): Root angulation

	$\bar{X}$	S.E.	S.D.	min	max	N
$M_{\bar{3}}$ m						
Gorilla	-5	0.54	3.3	-13	+3	37
Pan	+1	1.00	5.6	-13	+13	31
Pongo	-4	0.83	3.7	-10	+4	20
H.sapiens (pooled)	-9	1.06	5.5	-19	+2	27
Romano-British	-10	1.46	5.6	-19	-1	15
Aust.Aborigines	-7	1.46	5.1	-13	+2	12
$M_{\bar{3}}$ d						
Gorilla	-21	1.00	5.7	-38	-10	32
Pan	-14	1.06	5.7	-24	+2	29
Pongo	-14	0.96	4.2	-23	-8	19
H.sapiens (pooled)	-7	1.10	5.7	-23	+5	27
Romano-British	-8	1.66	6.4	-23	+5	15
Aust.Aborigines	-5	1.20	4.2	-13	+1	12
$I_{\bar{1}}$						
Gorilla	-2	0.73	4.0	-10	+4	31
Pan	-4	1.05	5.6	-11	+10	28
Pongo	-1	0.89	4.8	-9	+12	29
H.sapiens (pooled)	-2	0.75	3.8	-10	+4	25
Romano-British	-2	0.93	4.1	-10	+4	19
Aust.Aborigines	-1	1.17	2.9	-5	+3	6
$I_{\bar{2}}$						
Gorilla	+5	1.41	7.0	-7	+20	25
Pan	+4	1.11	5.4	-5	+17	24
Pongo	+4	1.04	5.7	-11	+12	30
H.sapiens (pooled)	+2	0.68	3.7	-5	+11	29
Romano-British	+3	0.74	3.1	-1	+11	17
Aust.Aborigines	+1	1.19	4.1	-5	+9	12
$3RP^{\bar{3}}$ l						
Gorilla	-4	0.65	4.1	-15	+10	39
Pan	-6	0.85	4.4	-13	+3	27
Pongo	-9	1.16	5.7	-23	+5	24
$3RP^{\bar{3}}$ mb						
Gorilla	+1	0.96	6.0	-11	+17	39
Pan	0	1.00	5.2	-9	+11	27
Pongo	0	1.22	6.0	-14	+10	24

D(vii): Root angulation

	$\bar{X}$	S.E.	S.D.	min	max	N
$3RP^{3}$ db						
Gorilla	-9	1.10	6.9	-22	+3	39
Pan	-12	1.21	6.3	-28	-2	27
Pongo	-9	1.28	6.3	-26	+2	24
$2RP^{3}$ l						
Pan	-7	-	-	-9	-6	3
Pongo	-8	-	-	-18	+2	2
H.sapiens (pooled)	-2	4.24	9.5	-13	+13	5
Romano-British	-1	-	-	-13	+13	3
Aust.Aborigines	-5	-	-	-5	-4	2
$2RP^{3}$ b						
Pan	-6	-	-	-10	-2	3
Pongo	-5	-	-	-11	+2	2
H.sapiens (pooled)	-5	3.27	7.3	-13	+6	5
Romano-British	-3	-	-	-13	+6	3
Aust.Aborigines	-8	-	-	-8	-7	2
$1RP^{3}$						
H.sapiens (pooled)	-1	1.16	5.9	-9	+12	26
Romano-British	0	1.73	6.7	-9	+12	15
Aust.Aborigines	-3	1.36	4.5	-9	+5	11
$3RP^{4}$ l						
Gorilla	-5	0.71	4.5	-17	+6	40
Pan	-2	2.29	5.1	-8	+6	5
Pongo	-7	0.83	4.3	-15	+3	27
$3RP^{4}$ mb						
Gorilla	-1	1.08	6.9	-15	+14	40
Pan	-1	1.75	3.9	-4	+6	5
Pongo	-3	1.04	5.4	-13	+8	27
$3RP^{4}$ db						
Gorilla	-11	0.94	6.0	-28	-1	40
Pan	-8	1.41	3.2	-12	-4	5
Pongo	-9	1.06	5.5	-22	+1	27
$2RP^{4}$ l						
Pan	-3	1.19	5.9	-17	+8	25
Pongo	-8	-	-	-11	-5	2

D(vii): Root angulation

	$\bar{X}$	S.E.	S.D.	min	max	N
$2RP^{\underline{4}}$ b						
Pan	-4	1.00	5.0	-13	+8	25
Pongo	-15	-	-	-20	-10	2
$1RP^{\underline{4}}$						
H.sapiens (pooled)	-3	0.84	4.8	-11	+12	32
Romano-British	-1	1.11	4.8	-8	+12	19
Aust.Aborigines	-6	0.87	3.1	-11	-2	13
$M^{\underline{1}}$ l						
Gorilla	-8	0.67	4.3	-17	+2	40
Pan	-8	0.99	5.5	-19	+1	31
Pongo	-10	0.72	4.1	-16	-1	32
H.sapiens (pooled)	-7	1.19	6.6	-19	+10	31
Romano-British	-9	1.31	5.6	-17	+1	18
Aust.Aborigines	-4	1.95	7.0	-19	+10	13
$M^{\underline{1}}$ mb						
Gorilla	-7	1.23	7.8	-21	+13	40
Pan	-1	1.10	6.1	-16	+13	31
Pongo	-12	1.28	7.2	-28	+2	32
H.sapiens (pooled)	-5	0.74	4.1	-15	+4	31
Romano-British	-4	0.94	4.0	-12	+4	18
Aust.Aborigines	-7	1.07	3.8	-15	-2	13
$M^{\underline{1}}$ db						
Gorilla	-16	0.98	6.2	-29	+1	40
Pan	-14	1.00	5.6	-25	-4	31
Pongo	-13	1.26	7.1	-29	+4	32
H.sapiens (pooled)	-12	0.96	5.4	-24	-4	31
Romano-British	-12	1.53	6.5	-24	-4	18
Aust.Aborigines	-11	0.97	3.5	-15	-6	13
$M^{\underline{2}}$ l						
Gorilla	-7	0.97	5.8	-20	+3	36
Pan	-8	1.01	5.5	-17	+3	30
Pongo	-12	0.94	5.1	-25	-3	29
H.sapiens (pooled)	-11	1.26	6.7	-23	+6	28
Romano-British	-11	1.48	5.6	-22	-2	14
Aust.Aborigines	-11	2.10	7.8	-23	+6	14

D(vii): Root angulation

	$\bar{X}$	S.E.	S.D.	min	max	N
M^2 mb						
Gorilla	-5	1.00	6.0	-16	+10	36
Pan	-1	0.91	5.0	-18	+7	30
Pongo	-5	1.15	6.2	-17	+9	29
H.sapiens (pooled)	-9	1.18	6.3	-22	+11	28
Romano-British	-9	1.14	4.3	-17	0	14
Aust.Aborigines	-9	2.12	8.0	-22	+11	14
M^2 db						
Gorilla	-4	1.13	6.8	-19	+10	36
Pan	-11	1.48	8.1	-31	+3	30
Pongo	-8	1.06	5.7	-17	+4	29
H.sapiens (pooled)	-11	0.92	4.8	-21	-1	28
Romano-British	-11	1.39	5.2	-20	-1	14
Aust.Aborigines	-11	1.25	4.7	-21	-4	14
M^3 1						
Gorilla	-17	1.40	8.5	-42	-3	37
Pan	-13	1.39	7.6	-31	0	30
Pongo	-20	1.12	5.5	-34	-12	24
H.sapiens (pooled)	-11	2.26	7.8	-23	+2	12
Romano-British	-10	-	-	-17	+1	4
Aust.Aborigines	-12	2.93	8.3	-23	+2	8
M^3 mb						
Gorilla	-8	1.15	7.0	-24	+5	37
Pan	-1	1.12	6.1	-11	+12	30
Pongo	-3	1.57	7.7	-16	+11	24
H.sapiens (pooled)	-12	2.06	7.1	-25	-2	12
Romano-British	-14	-	-	-25	-3	4
Aust.Aborigines	-10	2.13	6.0	-20	-2	8
M^3 db						
Gorilla	-12	1.24	7.6	-31	+3	37
Pan	-15	1.76	9.7	-32	0	30
Pongo	-20	1.59	7.8	-34	-7	24
H.sapiens (pooled)	-15	1.86	6.4	-24	-3	12
Romano-British	-10	-	-	-20	-3	4
Aust.Aborigines	-17	1.59	4.5	-24	-10	8

D(viii): Crown mesiodistal diameter

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$I_{\overline{1}}$							
Gorilla	7.0	0.17	0.9	5.1	8.7	12.9	28
Pan	7.2	0.15	0.8	5.6	8.3	10.7	27
Pongo	8.9	0.17	0.9	7.2	10.9	10.6	31
H.sapiens (pooled)	4.9	0.10	0.5	3.9	5.9	10.1	24
Romano-British	4.8	0.09	0.4	4.2	5.4	7.5	17
Aust.Aborigines	5.0	0.28	0.7	3.9	5.9	14.7	7
$I_{\overline{2}}$							
Gorilla	8.2	0.14	0.8	5.8	9.7	9.7	35
Pan	8.0	0.15	0.8	6.5	9.2	9.6	27
Pongo	8.8	0.15	0.8	7.4	10.1	9.2	29
H.sapiens (pooled)	5.8	0.10	0.5	5.0	7.2	9.4	30
Romano-British	5.6	0.08	0.4	5.0	6.2	6.3	20
Aust.Aborigines	6.1	0.22	0.7	5.1	7.2	11.7	10
$C_{\overline{1}}$							
Gorilla	13.3	0.35	2.1	8.5	18.7	16.0	38
Pan	11.2	0.24	1.4	9.0	14.2	12.1	31
Pongo	12.0	0.33	1.9	8.2	16.0	16.2	34
H.sapiens (pooled)	6.9	0.11	0.6	5.9	8.2	9.1	32
Romano-British	6.6	0.10	0.5	5.9	7.5	6.9	20
Aust.Aborigines	7.5	0.12	0.4	6.7	8.2	5.6	12
$P_{\overline{3}}$							
Gorilla	14.5	0.20	1.2	11.6	17.5	8.6	40
Pan	9.7	0.15	0.8	8.3	12.4	8.7	31
Pongo	12.1	0.18	1.1	10.1	14.7	8.8	34
H.sapiens (pooled)	7.0	0.13	0.7	5.8	8.9	10.5	33
Romano-British	6.6	0.11	0.5	5.8	7.6	7.5	20
Aust.Aborigines	7.6	0.18	0.6	6.5	8.9	8.4	13
$P_{\overline{4}}$							
Gorilla	11.6	0.13	0.9	10.0	13.5	7.3	40
Pan	8.0	0.09	0.5	6.8	9.0	6.3	31
Pongo	10.8	0.15	0.9	8.8	12.3	8.0	34
H.sapiens (pooled)	7.0	0.13	0.7	5.9	8.6	10.5	34
Romano-British	6.6	0.12	0.5	5.9	7.6	7.9	20
Aust.Aborigines	7.6	0.17	0.6	6.7	8.6	8.3	14

D(viii): Crown mesiodistal diameter

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$M_{\bar{1}}$							
Gorilla	15.4	0.17	1.0	12.9	17.8	6.8	40
Pan	11.0	0.11	0.6	9.7	12.2	5.5	31
Pongo	13.1	0.14	0.8	11.8	14.6	6.0	33
H.sapiens (pooled)	11.4	0.17	1.0	9.3	13.6	8.3	33
Romano-British	11.0	0.17	0.7	9.3	12.0	6.7	20
Aust.Aborigines	12.1	0.22	0.8	11.0	13.6	6.5	13
$M_{\bar{2}}$							
Gorilla	17.1	0.20	1.3	14.4	19.9	7.5	40
Pan	11.5	0.12	0.6	10.3	13.1	5.5	30
Pongo	13.7	0.18	1.0	12.0	16.2	7.3	33
H.sapiens (pooled)	11.0	0.21	1.2	9.2	13.8	10.9	34
Romano-British	10.3	0.16	0.7	9.2	11.6	6.7	20
Aust.Aborigines	12.1	0.23	0.9	10.7	13.8	7.2	14
$M_{\bar{3}}$							
Gorilla	17.3	0.22	1.4	13.6	20.1	7.9	39
Pan	10.9	0.14	0.8	9.2	12.3	6.9	31
Pongo	13.5	0.19	1.1	11.4	15.6	7.9	32
H.sapiens (pooled)	11.0	0.22	1.2	8.7	13.6	11.0	31
Romano-British	10.2	0.21	0.9	8.7	11.6	8.7	18
Aust.Aborigines	12.0	0.21	0.8	10.9	13.6	6.4	13
$I_{\bar{1}}$							
Gorilla	12.7	0.22	1.2	9.6	15.4	9.7	31
Pan	11.2	0.18	0.9	8.9	13.0	8.4	26
Pongo	13.7	0.22	1.2	11.3	15.9	8.5	29
H.sapiens (pooled)	8.2	0.13	0.7	7.2	9.3	8.0	25
Romano-British	8.1	0.13	0.6	7.2	8.9	6.9	19
Aust.Aborigines	8.3	0.38	0.9	7.4	9.3	11.2	6
$I_{\bar{2}}$							
Gorilla	8.9	0.19	1.1	6.4	11.8	12.1	32
Pan	8.7	0.19	0.9	6.1	9.9	10.1	22
Pongo	8.4	0.11	0.6	7.3	9.5	7.2	29
H.sapiens (pooled)	6.6	0.17	0.9	4.4	8.3	13.4	29
Romano-British	6.1	0.16	0.7	4.4	7.3	11.0	17
Aust.Aborigines	7.3	0.20	0.7	6.1	8.3	9.4	12

D(viii): Crown mesiodistal diameter

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
P^3							
Gorilla	11.7	0.13	0.8	9.8	13.8	7.0	40
Pan	8.3	0.10	0.6	7.3	9.4	6.7	31
Pongo	9.9	0.10	0.6	8.8	11.0	5.9	34
H.sapiens (pooled)	7.0	0.13	0.8	5.6	8.5	11.0	33
Romano-British	6.5	0.10	0.5	5.6	7.4	6.9	20
Aust.Aborigines	7.7	0.15	0.5	6.9	8.5	7.0	13
P^4							
Gorilla	11.2	0.11	0.7	9.6	13.1	6.4	40
Pan	7.5	0.11	0.6	6.5	9.2	7.9	30
Pongo	9.6	0.09	0.5	8.5	10.6	5.7	34
H.sapiens (pooled)	6.8	0.12	0.7	5.4	8.1	10.3	33
Romano-British	6.4	0.16	0.4	5.4	7.1	6.9	20
Aust.Aborigines	7.4	0.15	0.5	6.7	8.1	7.2	13
M^1							
Gorilla	14.6	0.16	1.0	12.2	16.8	7.0	39
Pan	10.4	0.13	0.7	8.5	12.0	6.8	30
Pongo	12.1	0.15	0.8	10.4	13.9	7.0	33
H.sapiens (pooled)	10.6	0.16	0.9	9.0	12.7	8.6	31
Romano-British	10.1	0.14	0.6	9.0	11.1	6.1	18
Aust.Aborigines	11.3	0.22	0.8	10.2	12.7	6.9	13
M^2							
Gorilla	15.9	0.20	1.3	13.6	18.7	7.9	40
Pan	10.5	0.13	0.7	9.0	12.3	6.6	30
Pongo	12.1	0.19	1.1	10.2	14.3	9.2	34
H.sapiens (pooled)	9.9	0.22	1.2	7.9	12.4	12.6	31
Romano-British	9.0	0.18	0.8	7.9	10.5	8.3	17
Aust.Aborigines	10.9	0.23	0.9	9.2	12.4	8.1	14
M^3							
Gorilla	14.9	0.21	1.3	11.9	17.7	8.9	40
Pan	9.6	0.25	0.8	7.9	12.3	8.3	30
Pongo	11.4	0.21	1.2	8.8	13.2	10.6	34
H.sapiens (pooled)	8.7	0.23	1.3	5.8	11.1	14.4	29
Romano-British	8.0	0.25	1.0	5.8	9.4	12.8	17
Aust.Aborigines	9.7	0.22	0.8	8.5	11.1	7.7	12

D(ix): Crown buccolingual diameter

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$I_{\overline{1}}$							
Gorilla	9.0	0.17	0.9	7.1	10.7	10.0	27
Pan	8.7	0.12	0.6	7.2	10.1	7.1	27
Pongo	9.5	0.15	0.9	7.8	11.2	8.9	31
H.sapiens (pooled)	5.9	0.09	0.5	5.0	6.7	7.8	24
Romano-British	5.8	0.11	0.4	5.0	6.4	7.5	17
Aust.Aborigines	6.2	0.15	0.4	5.6	6.7	6.5	7
$I_{\overline{2}}$							
Gorilla	9.9	0.19	1.1	7.5	12.8	11.4	36
Pan	9.0	0.15	0.8	7.7	10.9	8.3	27
Pongo	9.9	0.15	0.8	8.4	12.0	8.5	32
H.sapiens (pooled)	6.2	0.09	0.5	5.3	7.1	8.0	30
Romano-British	6.0	0.09	0.4	5.3	6.8	6.5	20
Aust.Aborigines	6.6	0.15	0.5	5.6	7.1	7.2	10
$C_{\overline{1}}$							
Gorilla	15.0	0.48	2.9	10.7	23.1	19.6	38
Pan	12.3	0.35	2.0	8.9	16.3	15.8	31
Pongo	13.3	0.35	2.0	9.5	17.1	15.4	34
H.sapiens (pooled)	7.7	0.14	0.8	6.3	9.7	9.9	30
Romano-British	7.4	0.13	0.6	6.3	8.4	7.6	19
Aust.Aborigines	8.4	0.19	0.6	7.4	9.7	7.7	11
$P_{\overline{3}}$							
Gorilla	13.0	0.25	1.6	10.0	18.2	12.2	40
Pan	9.0	0.16	0.9	7.2	10.7	9.8	31
Pongo	11.7	0.24	1.4	9.5	15.8	12.2	34
H.sapiens (pooled)	7.9	0.14	0.8	6.7	9.6	10.0	33
Romano-British	7.4	0.11	0.5	6.7	8.4	6.8	20
Aust.Aborigines	8.7	0.18	0.5	8.0	9.6	5.6	13
$P_{\overline{4}}$							
Gorilla	12.7	0.17	1.1	10.0	15.4	8.6	40
Pan	8.8	0.09	0.5	7.9	9.6	5.7	31
Pongo	11.4	0.15	0.9	9.6	13.0	7.8	34
H.sapiens (pooled)	8.3	0.13	0.8	6.6	9.4	9.1	34
Romano-British	7.9	0.15	0.7	6.6	8.9	8.2	20
Aust.Aborigines	8.8	0.15	0.6	7.8	9.4	6.4	14

D(ix): Crown buccolingual diameter

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$M_{\bar{1}}$							
Gorilla	13.3	0.16	1.0	11.1	15.7	7.5	40
Pan	9.9	0.10	0.6	8.7	10.8	5.7	31
Pongo	12.0	0.12	0.7	10.6	13.5	5.9	33
H.sapiens (pooled)	10.9	0.15	0.9	9.5	12.6	8.1	33
Romano-British	10.4	0.11	0.5	9.5	11.1	4.9	20
Aust.Aborigines	11.8	0.15	0.6	11.0	12.6	4.7	13
$M_{\bar{2}}$							
Gorilla	15.0	0.19	1.2	12.4	18.0	8.2	40
Pan	10.7	0.13	0.7	9.5	12.3	6.5	30
Pongo	12.6	0.17	1.0	10.2	14.6	7.9	33
H.sapiens (pooled)	10.5	0.19	1.1	8.2	12.5	10.6	34
Romano-British	9.7	0.16	0.7	8.2	10.9	7.5	20
Aust.Aborigines	11.5	0.14	0.5	11.0	12.5	4.5	14
$M_{\bar{3}}$							
Gorilla	14.5	0.18	1.1	11.9	17.3	7.7	39
Pan	10.2	0.12	0.7	8.4	11.5	6.5	31
Pongo	12.0	0.17	1.0	9.9	14.2	8.1	32
H.sapiens (pooled)	10.3	0.20	1.1	8.1	12.7	10.9	31
Romano-British	9.6	0.18	0.8	8.1	10.8	8.2	18
Aust.Aborigines	11.3	0.19	0.7	10.3	12.7	6.1	13
$I_{\bar{}}^{1}$							
Gorilla	10.5	0.17	0.9	8.5	12.8	8.8	29
Pan	9.0	0.13	0.7	7.9	10.2	7.6	26
Pongo	11.9	0.21	1.1	9.0	14.2	9.6	29
H.sapiens (pooled)	7.2	0.13	0.6	6.2	8.4	8.9	25
Romano-British	6.9	0.10	0.4	6.2	7.6	6.3	19
Aust.Aborigines	8.0	0.15	0.4	7.5	8.4	4.5	6
$I_{\bar{}}^{2}$							
Gorilla	9.6	0.23	1.3	7.8	13.5	13.5	31
Pan	8.4	0.12	0.6	7.3	9.6	6.7	22
Pongo	8.7	0.15	0.8	6.8	10.7	9.2	29
H.sapiens (pooled)	6.4	0.13	0.7	4.8	7.7	10.8	29
Romano-British	6.0	0.12	0.5	4.8	7.1	8.4	17
Aust.Aborigines	7.0	0.14	0.5	6.1	7.7	6.9	12

D(ix): Crown buccolingual diameter

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
P^3							
Gorilla	15.5	0.20	1.2	12.4	18.2	7.9	40
Pan	10.3	0.13	0.7	8.2	11.9	7.1	31
Pongo	12.4	0.14	0.8	10.9	14.3	6.7	34
H.sapiens (pooled)	9.4	0.19	1.1	7.1	11.7	11.8	33
Romano-British	8.7	0.18	0.8	7.1	10.1	9.3	20
Aust.Aborigines	10.4	0.16	0.6	9.5	11.7	5.5	13
P^4							
Gorilla	15.0	0.18	1.2	12.3	18.1	7.8	40
Pan	10.3	0.12	0.7	8.7	11.7	6.3	30
Pongo	12.8	0.14	0.8	11.0	14.2	6.4	34
H.sapiens (pooled)	9.4	0.16	0.9	7.9	11.6	9.9	33
Romano-British	9.0	0.16	0.7	7.9	10.2	8.2	20
Aust.Aborigines	10.2	0.19	0.7	9.4	11.6	6.7	13
M^1							
Gorilla	15.3	0.16	1.0	13.5	17.6	6.3	38
Pan	11.5	0.09	0.5	10.4	12.5	4.4	30
Pongo	13.2	0.14	0.8	11.8	14.9	6.0	33
H.sapiens (pooled)	11.9	0.17	1.0	9.9	13.7	8.2	31
Romano-British	11.2	0.15	0.6	9.9	11.9	5.5	18
Aust.Aborigines	12.8	0.16	0.6	12.0	13.7	4.5	13
M^2							
Gorilla	16.4	0.19	1.2	13.8	19.4	7.3	40
Pan	11.9	0.13	0.7	10.6	13.8	5.8	29
Pongo	13.8	0.17	1.0	12.2	16.4	7.3	34
H.sapiens (pooled)	12.0	0.25	1.4	9.6	15.1	11.4	31
Romano-British	11.0	0.17	0.7	9.6	12.1	6.4	17
Aust.Aborigines	13.3	0.25	0.9	12.1	15.1	6.9	14
M^3							
Gorilla	15.4	0.21	1.3	12.2	18.7	8.5	40
Pan	11.3	0.11	0.6	9.8	12.8	5.6	31
Pongo	13.3	0.14	0.8	11.8	15.1	6.3	34
H.sapiens (pooled)	11.2	0.33	1.8	6.6	14.4	15.8	29
Romano-British	10.1	0.32	1.3	6.6	12.2	13.1	17
Aust.Aborigines	12.6	0.32	1.1	11.2	14.4	8.7	12

D(x): Jaw dimensions

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
Palatal length							
Gorilla	93.6	2.05	12.7	72.6	122.5	13.5	38
Pan	71.3	0.94	5.3	60.4	83.3	7.4	31
Pongo	76.5	1.19	6.9	63.7	88.0	9.1	34
H.sapiens (pooled)	50.1	1.04	6.0	39.3	65.1	12.1	34
Romano-British	46.4	0.85	3.8	39.3	54.1	8.2	20
Aust.Aborigines	55.5	1.15	4.3	49.9	65.1	7.7	14
Palatal breadth							
Gorilla	71.8	0.86	5.4	62.5	82.0	7.5	39
Pan	60.7	0.52	2.8	56.0	66.7	4.7	31
Pongo	68.2	0.86	5.0	60.2	78.3	7.3	34
H.sapiens (pooled)	63.1	0.92	5.4	52.8	72.9	8.5	34
Romano-British	61.0	1.13	5.1	52.8	72.8	8.3	20
Aust.Aborigines	66.2	1.13	4.2	59.8	72.9	6.4	14
Mandib. length							
Gorilla	110.5	1.61	10.1	90.6	135.5	9.1	39
Pan	84.6	0.92	5.1	74.6	95.1	6.1	31
Pongo	97.8	1.34	7.8	79.4	113.1	8.0	34
H.sapiens (pooled)	65.0	1.09	6.4	50.4	76.6	9.8	34
Romano-British	61.1	0.96	4.3	50.4	68.9	7.0	20
Aust.Aborigines	70.5	1.22	4.6	60.8	76.6	6.5	14
Mandib. depth $C_{\overline{1}}$							
Gorilla	48.2	0.92	5.8	36.4	60.4	12.1	40
Pan	34.2	0.62	3.5	27.8	41.1	10.2	31
Pongo	46.3	1.05	6.0	33.1	60.4	13.1	33
H.sapiens (pooled)	30.8	0.64	3.7	21.8	39.6	12.2	34
Romano-British	30.6	0.81	3.6	25.1	39.6	11.8	20
Aust.Aborigines	31.1	1.08	4.0	21.8	37.8	13.0	14
Mandib. depth $M_{\overline{1}}$							
Gorilla	38.5	0.77	4.9	27.4	48.4	12.7	40
Pan	28.6	0.52	2.9	23.5	34.8	10.0	31
Pongo	37.6	0.91	5.3	27.3	48.5	14.1	34
H.sapiens (pooled)	28.5	0.54	3.1	22.2	35.6	11.0	34
Romano-British	28.7	0.67	3.0	23.9	35.6	10.5	20
Aust.Aborigines	28.3	0.92	3.4	22.2	35.2	12.1	14

D(x): Jaw dimensions

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
Mandib.depth $M_{\overline{2}}$							
Gorilla	36.2	0.68	4.3	26.6	46.5	11.8	40
Pan	27.1	0.49	2.7	22.5	32.6	10.1	31
Pongo	35.5	0.78	4.5	27.7	46.3	12.8	34
H.sapiens (pooled)	26.2	0.44	2.6	21.8	32.3	9.8	34
Romano-British	26.5	0.57	2.6	22.1	32.3	9.7	20
Aust.Aborigines	25.9	0.71	2.7	21.8	31.0	10.3	14
Mandib. depth $M_{\overline{3}}$							
Gorilla	39.0	0.67	4.3	29.5	50.2	10.9	40
Pan	27.8	0.46	2.6	24.2	31.8	9.2	31
Pongo	36.6	0.77	4.4	30.3	50.4	12.0	33
H.sapiens (pooled)	26.5	0.48	2.7	21.0	31.5	10.2	32
Romano-British	27.4	0.64	2.7	21.7	31.5	10.0	18
Aust.Aborigines	25.4	0.62	2.3	21.0	29.4	9.1	14

Appendix E: Statistical summaries for the indices computed from root, crown and jaw dimensions in the pongids and Homo sapiens (pooled sexes)

E (i) : Location of bifurcation index

E (ii) : Root robusticity index

E (iii) : Height of bifurcation index

E (iv) : Root divergence

E(1): Location of bifurcation index

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$2RP_{\overline{3}}$							
Gorilla	51.2	0.71	4.5	39.0	63.2	8.7	40
Pan	52.6	0.77	3.6	46.7	61.9	6.9	22
Pongo	52.1	0.66	3.8	43.4	58.3	7.3	33
H.sapiens (pooled)	50.8	–	–	–	–	–	1
$2RP_{\overline{4}}$							
Gorilla	46.5	0.48	3.0	41.7	56.2	6.5	39
Pan	48.7	0.76	4.2	42.9	57.4	8.7	31
Pongo	47.7	0.56	3.3	42.6	55.2	6.9	34
$M_{\overline{1}}$							
Gorilla	46.8	0.44	2.8	39.5	53.0	5.9	40
Pan	50.5	0.60	3.4	42.9	59.6	6.7	31
Pongo	49.2	0.49	2.8	42.7	56.2	5.8	34
H.sapiens (pooled)	51.6	0.56	3.2	44.4	57.1	6.3	33
$M_{\overline{2}}$							
Gorilla	48.0	0.52	3.3	40.7	55.2	6.9	40
Pan	49.7	0.60	3.3	44.0	59.8	6.7	31
Pongo	49.3	0.58	3.4	45.0	58.7	6.8	34
H.sapiens (pooled)	50.5	0.64	3.7	41.2	58.3	7.3	33
$M_{\overline{3}}$							
Gorilla	48.5	0.60	3.7	41.1	59.7	7.7	39
Pan	51.5	0.89	5.0	36.8	58.3	9.6	31
Pongo	51.3	0.72	4.2	36.4	58.9	8.2	34
H.sapiens (pooled)	52.0	0.93	4.9	44.0	63.8	9.5	28

E(11): Root robusticity index

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$C_{\bar{1}}$							
Gorilla	33.3	1.32	7.2	24.0	59.6	21.8	30
Pan	30.3	0.75	3.9	20.5	41.3	12.9	27
Pongo	25.8	1.19	4.6	18.6	33.2	17.9	15
H.sapiens (pooled)	31.0	1.07	6.0	17.7	42.9	19.2	31
$2RP_{\bar{3}}$ m							
Gorilla	25.6	0.52	3.3	18.4	33.8	12.7	39
Pan	21.8	0.65	3.0	15.8	26.4	14.0	22
Pongo	19.8	0.65	3.6	13.7	25.9	17.9	30
H.sapiens (pooled)	11.0	–	–	–	–	–	1
$2RP_{\bar{3}}$ d							
Gorilla	24.6	0.58	3.6	17.5	33.0	14.8	39
Pan	20.9	0.65	3.1	16.7	29.5	14.6	22
Pongo	19.7	0.59	3.2	13.0	26.0	16.4	30
H.sapiens (pooled)	17.1	–	–	–	–	–	1
$1RP_{\bar{3}}$							
Pan	35.1	2.16	6.5	27.2	46.9	18.5	9
Pongo	24.0	–	–	–	–	–	1
H.sapiens (pooled)	22.4	0.69	3.8	16.4	43.1	17.1	31
$2RP_{\bar{4}}$ m							
Gorilla	19.3	0.35	2.1	15.2	24.2	10.9	37
Pan	19.2	0.54	3.0	14.4	26.1	15.5	30
Pongo	17.2	0.55	3.1	11.1	23.2	18.1	32
$2RP_{\bar{4}}$ d							
Gorilla	23.5	0.40	2.4	19.2	28.3	10.4	38
Pan	22.2	0.67	3.7	14.3	31.7	16.5	30
Pongo	19.7	0.60	3.4	13.5	29.0	17.3	32
$1RP_{\bar{4}}$							
H.sapiens (pooled)	23.5	0.62	3.6	16.9	29.5	15.2	33
$M_{\bar{1}}$ m							
Gorilla	25.6	0.78	4.9	16.3	37.9	19.2	40
Pan	28.9	0.72	4.0	21.6	35.5	13.9	31
Pongo	19.1	0.53	3.1	14.8	27.2	16.2	34
H.sapiens (pooled)	26.0	0.73	4.2	20.0	36.3	16.1	33

E(ii): Root robusticity index

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
M_1 d							
Gorilla	29.7	0.67	4.2	21.3	40.4	14.2	40
Pan	27.3	0.49	2.7	22.5	33.1	9.9	31
Pongo	20.7	0.67	3.9	13.6	28.8	18.9	34
H.sapiens (pooled)	24.7	0.49	2.8	19.4	30.3	11.3	33
M_2 m							
Gorilla	26.0	0.66	4.2	18.1	37.7	15.9	40
Pan	29.0	0.64	3.5	24.2	35.8	12.2	31
Pongo	21.2	0.79	4.4	13.9	32.1	20.6	31
H.sapiens (pooled)	23.4	0.55	3.2	17.3	32.3	13.4	33
M_2 d							
Gorilla	33.1	0.69	4.3	22.8	45.3	13.0	39
Pan	30.5	0.76	4.2	24.6	38.2	13.8	31
Pongo	24.6	0.88	4.6	15.9	35.6	18.8	28
H.sapiens (pooled)	26.9	0.66	3.8	17.5	34.6	14.2	33
M_3 m							
Gorilla	29.9	0.80	4.9	20.1	45.0	16.2	37
Pan	37.0	1.01	5.6	27.5	50.0	15.3	31
Pongo	24.5	0.97	4.3	18.0	36.5	17.7	20
H.sapiens (pooled)	28.4	0.73	3.8	21.6	35.7	13.3	27
M_3 d							
Gorilla	42.1	1.32	7.5	30.5	57.0	17.7	32
Pan	40.3	1.25	6.7	28.7	52.6	16.7	29
Pongo	30.2	2.08	9.0	15.9	56.1	29.9	19
H.sapiens (pooled)	31.0	0.92	4.8	21.7	40.6	15.4	27
$3RP^3$ l							
Gorilla	38.3	1.12	7.0	26.8	57.9	18.3	39
Pan	30.2	0.75	3.9	23.1	37.2	12.9	27
Pongo	25.7	0.93	4.5	19.2	36.0	17.7	24
$3RP^3$ mb							
Gorilla	24.3	0.87	5.4	13.9	38.4	22.4	39
Pan	25.4	1.06	5.5	16.2	36.7	21.7	27
Pongo	19.0	0.83	4.1	11.7	26.5	21.5	24
$3RP^3$ db							
Gorilla	20.3	0.67	4.2	12.1	31.3	20.5	39
Pan	23.7	0.93	4.8	18.0	39.3	20.4	27
Pongo	17.0	0.71	3.5	13.1	25.2	20.5	24

E(11): Root robusticity index

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$2RP^{3}$ l							
Gorilla	30.9	–	–	26.0	38.9	–	3
Pan	24.5	–	–	20.6	28.5	–	2
Pongo	27.7	1.61	3.6	22.2	31.8	13.0	5
$2RP^{3}$ b							
Gorilla	33.5	–	–	32.0	34.4	–	3
Pan	22.4	–	–	22.3	22.4	–	2
Pongo	23.6	1.43	3.2	20.5	27.9	13.6	5
$1RP^{3}$							
H.sapiens (pooled)	23.1	0.50	2.5	19.1	29.1	10.7	25
$3RP^{4}$ l							
Gorilla	43.6	1.07	6.8	33.7	63.9	15.6	40
Pan	33.1	2.12	4.7	27.7	40.6	14.3	5
Pongo	28.5	1.11	5.8	19.8	41.4	20.3	27
$3RP^{4}$ mb							
Gorilla	21.5	0.79	5.0	11.6	37.6	23.4	40
Pan	20.6	1.37	1.4	18.0	25.0	14.9	5
Pongo	17.1	0.60	3.1	10.0	23.4	18.2	27
$3RP^{4}$ db							
Gorilla	20.7	0.65	4.1	10.1	29.4	19.9	40
Pan	21.9	0.83	1.9	19.6	23.7	8.4	5
Pongo	19.5	0.61	3.2	11.7	26.9	16.3	27
$2RP^{4}$ l							
Pan	33.2	0.95	4.7	26.8	44.9	14.3	25
Pongo	27.3	–	–	25.6	29.0	–	2
$2RP^{4}$ b							
Pan	27.6	1.18	5.9	18.6	37.9	21.4	25
Pongo	22.1	–	–	21.6	22.5	–	2
$1RP^{4}$							
H.sapiens (pooled)	22.6	0.48	2.7	16.0	27.7	11.9	32
M^{1} l							
Gorilla	52.2	1.33	8.4	38.7	73.6	16.1	40
Pan	39.7	1.10	6.1	24.6	52.3	15.4	31
Pongo	43.3	1.18	6.7	30.3	59.4	15.5	32
H.sapiens (pooled)	36.5	0.93	5.2	24.4	47.3	14.2	31

E(ii): Root robusticity index

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
M_{-}^{1} mb							
Gorilla	27.6	0.99	6.3	17.0	48.3	22.7	40
Pan	29.3	0.98	5.4	19.0	41.0	18.6	31
Pongo	22.4	0.78	4.4	15.0	31.3	19.6	32
H.sapiens (pooled)	25.4	0.73	4.1	18.6	36.9	16.0	31
M_{-}^{1} db							
Gorilla	27.6	0.75	4.8	19.7	38.2	17.2	40
Pan	27.4	0.87	4.9	19.4	38.0	17.7	31
Pongo	22.3	0.68	3.8	16.1	30.9	17.2	32
H.sapiens (pooled)	24.7	0.71	4.0	16.7	32.6	16.0	31
M_{-}^{2} l							
Gorilla	63.6	1.58	9.5	48.7	88.8	14.9	36
Pan	43.8	1.16	6.3	30.4	54.1	14.5	30
Pongo	46.0	1.54	8.3	27.7	65.3	18.0	29
H.sapiens (pooled)	33.8	0.96	5.1	23.2	46.7	15.0	28
M_{-}^{2} mb							
Gorilla	27.3	0.79	4.7	18.3	36.2	17.3	36
Pan	28.2	0.79	4.3	20.7	38.5	15.4	30
Pongo	24.8	0.97	5.2	17.8	37.3	21.1	29
H.sapiens (pooled)	23.2	0.65	3.5	16.7	33.3	14.9	28
M_{-}^{2} db							
Gorilla	29.6	1.15	6.9	17.6	45.7	23.4	36
Pan	26.6	0.96	5.2	15.6	38.0	19.7	30
Pongo	23.5	0.84	4.5	17.9	35.3	19.1	29
H.sapiens (pooled)	23.6	0.66	3.5	16.8	30.7	14.9	28
M_{-}^{3} l							
Gorilla	55.3	1.31	8.0	37.8	71.2	14.4	37
Pan	41.4	1.21	6.6	26.3	58.8	16.0	30
Pongo	47.1	1.81	8.8	33.0	61.6	18.8	24
H.sapiens (pooled)	34.8	1.70	5.9	25.0	43.0	16.9	12
M_{-}^{3} mb							
Gorilla	27.8	0.75	4.6	18.3	39.3	16.4	37
Pan	28.6	0.80	4.4	20.8	38.8	15.3	30
Pongo	25.7	1.04	5.1	16.9	34.6	19.8	24
H.sapiens (pooled)	24.4	1.43	5.0	15.0	32.4	20.4	12
M_{-}^{3} db							
Gorilla	28.2	0.78	4.8	19.6	36.8	16.9	37
Pan	27.6	1.19	6.5	15.8	49.2	23.6	30
Pongo	27.3	1.21	6.0	14.7	39.6	21.8	24
H.sapiens (pooled)	22.1	1.15	4.0	13.3	27.1	18.0	12

E(iii): Height of bifurcation index

	$\bar{X}$	S.E.	S.D.	min	max	V	N
$2RP_3$							
Gorilla	21.0	1.31	8.2	7.4	37.4	38.8	39
Pan	26.7	1.93	9.1	12.9	49.0	34.0	22
Pongo	25.4	1.25	6.8	9.4	37.2	27.0	30
H.sapiens (pooled)	48.5	–	–	–	–	–	1
$2RP_4$							
Gorilla	27.9	0.89	5.4	16.8	40.6	19.4	37
Pan	31.5	1.89	10.5	20.9	77.4	33.4	31
Pongo	22.3	0.86	4.9	13.8	36.5	21.9	32
M_1							
Gorilla	18.6	0.49	3.1	12.4	27.4	16.7	40
Pan	23.2	0.67	3.7	16.8	30.6	16.0	31
Pongo	20.5	0.55	3.2	12.8	27.9	15.6	34
H.sapiens (pooled)	29.5	0.74	4.3	21.6	40.0	14.4	33
M_2							
Gorilla	21.8	0.71	4.4	13.9	32.4	20.3	39
Pan	26.4	1.09	6.1	15.6	49.0	23.1	31
Pongo	21.8	0.73	3.8	13.5	28.4	17.6	28
H.sapiens (pooled)	31.3	0.97	5.6	24.0	44.6	17.8	33
M_3							
Gorilla	23.8	0.80	4.5	14.0	33.6	19.0	32
Pan	32.1	1.30	7.0	17.1	47.3	21.7	29
Pongo	25.3	0.93	4.1	19.9	34.2	16.1	19
H.sapiens (pooled)	36.3	1.30	6.8	26.4	54.1	18.7	27
$3RP^3$							
Gorilla	22.2	1.01	6.3	8.8	33.1	28.5	39
Pan	33.9	1.83	9.5	13.5	56.2	28.1	27
Pongo	28.9	1.28	6.3	20.2	50.0	21.8	24
$3RP^4$							
Gorilla	27.6	0.91	5.8	14.2	37.3	20.9	40
Pan	32.1	4.59	10.3	20.4	43.4	31.9	5
Pongo	30.4	1.35	7.0	19.6	48.3	23.0	27
M^1							
Gorilla	17.6	1.24	7.8	6.2	50.7	44.5	40
Pan	24.0	1.10	6.2	13.5	37.8	25.6	31
Pongo	24.2	1.17	6.6	14.2	37.5	27.4	32
H.sapiens (pooled)	31.3	1.35	7.5	19.9	48.2	24.1	31

E(iii): Height of bifurcation index

	$\bar{X}$	S.E.	S.D.	min	max	V	N
M^2							
Gorilla	18.3	1.19	7.2	6.4	37.6	39.2	36
Pan	25.5	1.58	8.7	9.4	41.0	34.0	30
Pongo	23.5	0.94	5.1	16.2	34.4	21.6	29
H.sapiens (pooled)	35.4	1.77	9.3	21.4	62.8	26.4	28
M^3							
Gorilla	21.1	1.32	8.0	6.3	36.3	38.0	37
Pan	32.1	1.62	8.9	17.6	52.3	27.6	30
Pongo	24.5	1.79	8.8	8.5	44.5	35.8	24
H.sapiens (pooled)	36.9	1.56	5.4	25.4	45.7	14.7	12

E(iv): Root divergence

	$\bar{X}$	S.E.	S.D.	min	max	N
$2RP_3$						
Gorilla	-7	0.92	5.8	-23	+3	39
Pan	-1	1.30	6.1	-13	+9	22
Pongo	0	0.95	5.2	-10	+14	30
H.sapiens (pooled)	-6	-	-	-	-	1
$2RP_4$						
Gorilla	+4	0.80	4.9	-6	+14	37
Pan	+6	1.21	6.8	-8	+19	31
Pongo	+5	1.12	6.3	-10	+18	32
M_1						
Gorilla	+13	0.80	5.0	+4	+28	40
Pan	+9	1.17	6.5	-2	+29	31
Pongo	+7	0.83	4.8	-1	+17	34
H.sapiens (pooled)	+8	1.14	6.5	-5	+22	33
M_2						
Gorilla	+10	0.75	4.7	+1	+21	39
Pan	+9	0.96	5.4	-2	+19	31
Pongo	+8	1.06	5.6	-1	+20	28
H.sapiens (pooled)	0	0.95	5.4	-13	+11	33
M_3						
Gorilla	+16	1.02	5.8	+4	+29	32
Pan	+15	1.37	7.4	-6	+27	29
Pongo	+10	1.36	5.9	+4	+24	19
H.sapiens (pooled)	-2	1.20	6.2	-16	+8	27
$3RP^3$						
Gorilla	+10	1.34	8.4	-9	+25	27
Pan	+12	1.37	7.1	+1	+27	27
Pongo	+9	1.45	7.1	-5	+28	24
$3RP^4$						
Gorilla	+10	1.38	8.7	-9	+26	40
Pan	+7	2.94	6.6	+1	+18	5
Pongo	+6	0.97	5.1	-4	+14	27
M^1						
Gorilla	+9	1.35	8.6	-4	+28	40
Pan	+13	1.39	7.8	-5	+29	31
Pongo	+1	1.32	7.4	-11	+15	32
H.sapiens (pooled)	+7	1.20	6.7	-7	+21	31

E(iv): Root divergence

	$\bar{X}$	S.E.	S.D.	min	max	N
M^2						
Gorilla	0	1.20	7.2	-14	+21	36
Pan	+10	1.62	8.9	-5	+37	30
Pongo	+3	1.31	7.1	-10	+14	29
H.sapiens (pooled)	+2	1.40	7.4	-10	+20	28
M^3						
Gorilla	+5	1.27	7.7	-12	+18	37
Pan	+14	2.39	13.1	-3	+44	30
Pongo	+17	2.22	10.9	-1	+41	24
H.sapiens (pooled)	+3	2.19	7.6	-11	+13	12

Appendix F : Statistical tests of significance for the mean values and variances of the root, crown and jaw dimensions and indices in the comparative samples

F (i) : The pongids

F (ii) : *Homo sapiens*/the pongids

F (iii) : Romano-British/Australian Aborigines

Abbreviations:

n.MD	neck mesiodistal diameter
l.b.	location of bifurcation
l.b.i.	location of bifurcation index
a.r.h.	actual root height
p.r.h.	projected root height
r.MD	root mesiodistal diameter
r.r.	root robusticity
h.b.	height of bifurcation
h.b.i.	height of bifurcation index
r.ang	root angulation
r.div	root divergence
c.MD	crown mesiodistal diameter
c.BL	crown buccolingual diameter
p.l.	palatal length
p.b.	palatal breadth
m.l.	mandibular length
m.d.$C_{\overline{1}}$	mandibular depth $C_{\overline{1}}$
m.d.$M_{\overline{1}}$	mandibular depth $M_{\overline{1}}$
m.d.$M_{\overline{2}}$	mandibular depth $M_{\overline{2}}$
m.d.$M_{\overline{3}}$	mandibular depth $M_{\overline{3}}$
m.r.	mesial root
d.r.	distal root
l.r.	lingual root
mb.r.	mesiobuccal root
db.r.	distobuccal root

F (1) : The pongids

	t-test			F-ratio		
	Gorilla /Pongo	Gorilla /Pan	Pan/ Pongo	Gorilla /Pongo	Gorilla /Pan	Pan/ Pongo
I_1						
n.MD	<.01	NS	<.001	NS	NS	NS
a.r.h.	NS	<.001	<.001	NS	NS	NS
p.r.h.	NS	<.001	<.001	NS	NS	NS
r.ang	NS	NS	NS	NS	NS	<.01
c.MD	<.001	NS	<.001	NS	NS	NS
c.BL	NS	NS	<.001	NS	NS	NS
I_2						
n.MD	NS	NS	NS	NS	NS	NS
a.r.h.	NS	<.001	<.001	NS	NS	NS
p.r.h.	NS	<.001	<.001	NS	NS	NS
r.ang	NS	NS	NS	NS	NS	NS
c.MD	<.01	NS	.001	NS	NS	NS
c.BL	NS	.001	<.001	NS	NS	NS
C_1						
n.MD	NS	.001	NS	NS	NS	NS
a.r.h.	NS	<.001	<.001	NS	NS	NS
r.MD	<.01	<.001	NS	NS	.001	NS
r.r.	.001	NS	<.01	NS	<.01	NS
c.MD	<.01	<.001	NS	NS	NS	NS
c.BL	<.01	<.001	NS	NS	NS	NS
P_3						
n.MD	<.001	<.001	<.001	NS	NS	NS
l.b.	<.001	<.001	<.001	NS	<.01	NS
l.b.i.	NS	NS	NS	NS	NS	NS
h.b.	.001	NS	<.01	NS	NS	NS
h.b.i.	NS	NS	NS	NS	NS	NS
m.r.						
a.r.h.	.001	<.001	<.001	NS	NS	NS
p.r.h.	.001	<.001	<.001	NS	NS	NS
r.MD	<.001	<.001	<.001	NS	NS	NS
r.r.	<.001	<.001	NS	NS	NS	NS
r.ang	NS	NS	NS	NS	NS	NS

F (1) : The pongids

	t-test			F-ratio		
	Gorilla /Pongo	Gorilla /Pan	Pan/ Pongo	Gorilla /Pongo	Gorilla /Pan	Pan/ Pongo
d.r.						
a.r.h.	NS	<.001	<.001	NS	NS	NS
p.r.h.	NS	<.001	<.001	NS	NS	NS
r.MD	<.001	<.001	<.001	NS	NS	NS
r.r.	<.001	<.001	NS	NS	NS	NS
r.ang	<.001	<.001	NS	NS	NS	NS
r.div	<.001	.001	NS	NS	NS	NS
c.MD	<.001	<.001	<.001	NS	NS	NS
c.BL	<.001	<.001	<.001	NS	.001	.01
P_4						
n.MD	<.001	<.001	<.001	NS	NS	NS
l.b.	<.01	<.001	<.001	NS	NS	NS
l.b.i.	NS	NS	NS	NS	NS	NS
h.b.	<.01	NS	NS	NS	NS	NS
h.b.i.	<.001	NS	<.001	NS	<.001	<.001
m.r.						
a.r.h.	<.01	<.001	<.001	.001	NS	.01
p.r.h.	<.01	<.001	<.001	<.001	NS	.01
r.MD	NS	<.001	<.001	NS	NS	NS
r.r.	<.01	NS	NS	NS	NS	NS
r.ang	NS	NS	NS	NS	NS	NS
d.r.						
a.r.h.	NS	<.001	<.001	.001	NS	<.01
p.r.h.	NS	<.001	<.001	.001	NS	.001
r.MD	<.001	<.001	<.001	NS	NS	NS
r.r.	<.001	NS	<.01	NS	NS	NS
r.ang	<.01	NS	NS	NS	NS	NS
r.div	NS	NS	NS	NS	NS	NS
c.MD	<.001	<.001	<.001	NS	<.01	<.01
c.BL	<.001	<.001	<.001	NS	<.001	<.01
M_1						
n.MD	<.001	<.001	<.001	NS	<.001	NS
l.b.	<.001	<.001	<.001	NS	NS	NS
l.b.i.	<.001	<.001	NS	NS	NS	NS
h.b.	<.001	NS	<.001	NS	NS	NS
h.b.i.	.01	<.001	<.01	NS	NS	NS

F (1) : The pongids

	t-test			F-ratio		
	Gorilla /Pongo	Gorilla /Pan	Pan/ Pongo	Gorilla /Pongo	Gorilla /Pan	Pan/ Pongo
m.r.						
a.r.h.	<.001	<.001	<.001	NS	<.01	.001
p.r.h.	<.001	<.001	<.001	NS	.01	.001
r.MD	<.001	<.001	NS	NS	.001	NS
r.r.	<.001	<.01	<.001	<.01	NS	NS
r.ang	NS	NS	<.001	NS	NS	NS
d.r.						
a.r.h.	NS	<.001	<.001	NS	.001	<.001
p.r.h.	NS	<.001	<.001	NS	<.001	<.001
r.MD	<.001	<.001	NS	NS	<.01	NS
r.r.	<.001	<.01	<.001	NS	NS	NS
r.ang	<.001	<.001	NS	NS	NS	NS
r.div	<.001	<.01	NS	NS	NS	NS
c.MD	<.001	<.001	<.001	NS	<.01	NS
c.BI	<.001	<.001	<.001	NS	<.01	NS
M_2						
n.MD	<.001	<.001	<.001	NS	.001	NS
l.b.	<.001	<.001	<.001	NS	<.001	NS
l.b.1.	NS	NS	NS	NS	NS	NS
h.b.	NS	<.001	<.001	NS	NS	NS
h.b.1.	NS	<.001	.001	NS	NS	NS
m.r.						
a.r.h.	NS	<.001	<.001	NS	<.01	<.001
p.r.h.	NS	<.001	<.001	NS	<.01	<.001
r.MD	<.001	<.001	.001	NS	<.001	<.001
r.r.	<.001	<.01	<.001	NS	NS	NS
r.ang	NS	<.001	NS	NS	NS	NS
d.r.						
a.r.h.	NS	<.001	<.001	NS	NS	.001
p.r.h.	NS	<.001	<.001	NS	NS	<.001
r.MD	<.001	<.001	<.001	NS	.001	NS
r.r.	<.001	NS	<.001	NS	NS	NS
r.ang	<.001	<.001	NS	NS	NS	NS
r.div	NS	NS	NS	NS	NS	NS

F (1) : The pongids

	t-test			F-ratio		
	Gorilla /Pongo	Gorilla /Pan	Pan/ Pongo	Gorilla /Pongo	Gorilla /Pan	Pan/ Pongo
c.MD	<.001	<.001	<.001	NS	<.001	NS
c.BL	<.001	<.001	<.001	NS	<.01	NS
M_3						
n.MD	<.001	<.001	<.001	NS	<.001	<.01
l.b.	<.001	<.001	<.001	NS	NS	NS
l.b.i.	<.01	<.01	NS	NS	NS	NS
h.b.	NS	NS	<.001	NS	NS	NS
h.b.i.	NS	<.001	<.001	NS	NS	NS
m.r.						
a.r.h.	NS	<.001	<.001	NS	<.01	<.001
p.r.h.	NS	<.001	<.001	NS	<.01	<.001
r.MD	<.001	<.001	NS	NS	NS	NS
r.r.	<.001	<.001	<.001	NS	NS	NS
r.ang	NS	<.001	<.01	NS	<.01	NS
d.r.						
a.r.h.	NS	<.001	<.001	NS	NS	.001
p.r.h.	<.01	<.001	<.001	NS	NS	<.001
r.MD	<.001	<.001	<.001	NS	NS	NS
r.r.	<.001	NS	<.001	NS	NS	NS
r.ang	<.001	<.001	NS	NS	NS	NS
r.div	.001	NS	NS	NS	NS	NS
c.MD	<.001	<.001	<.001	NS	.001	NS
c.BL	<.001	<.001	<.001	NS	<.01	NS
I^1						
n.MD	NS	<.001	<.001	NS	NS	NS
a.r.h.	NS	<.001	<.01	NS	NS	NS
p.r.h.	NS	<.001	<.01	NS	NS	NS
r.ang	NS	NS	NS	NS	NS	NS
c.MD	<.01	<.001	<.001	NS	NS	NS
c.BL	<.001	<.001	<.001	NS	NS	NS
I^2						
n.MD	<.001	<.01	NS	NS	<.01	NS
a.r.h.	NS	<.001	<.001	NS	NS	NS
p.r.h.	NS	<.001	<.001	NS	NS	NS
r.ang	NS	NS	NS	NS	NS	NS
c.MD	NS	NS	NS	<.01	NS	NS
c.BL	.001	<.001	NS	NS	<.001	NS

F (1) : The pongids

	t-test			F-ratio		
	Gorilla /Pongo	Gorilla /Pan	Pan/ Pongo	Gorilla /Pongo	Gorilla /Pan	Pan/ Pongo
p^3						
l.b.	<.001	<.001	<.001	NS	NS	NS
h.b.	NS	NS	<.01	NS	NS	NS
h.b.1.	<.001	<.001	NS	NS	NS	NS
l.r.						
a.r.h.	NS	<.001	<.001	NS	.001	NS
p.r.h.	NS	<.001	<.001	NS	.001	NS
r.MD	<.001	<.001	<.001	NS	<.01	NS
r.r.	<.001	<.001	<.001	NS	<.01	NS
r.ang	.001	NS	NS	NS	NS	NS
mb.r.						
a.r.h.	NS	<.001	<.001	NS	<.01	NS
p.r.h.	NS	<.001	<.001	NS	<.01	NS
r.MD	<.001	<.001	NS	NS	<.01	NS
r.r.	<.001	NS	<.001	NS	NS	NS
r.ang	NS	NS	NS	NS	NS	NS
db.r.						
a.r.h.	NS	<.001	<.001	NS	<.001	NS
p.r.h.	NS	<.001	<.001	NS	<.001	NS
r.MD	<.001	<.001	NS	NS	NS	NS
r.r.	<.01	<.01	<.001	NS	NS	NS
r.ang	NS	NS	NS	NS	NS	NS
r.div	NS	NS	NS	NS	NS	NS
c.MD	<.001	<.001	<.001	NS	NS	NS
c.BL	<.001	<.001	<.001	NS	<.01	NS
p^4						
l.b.	<.001	<.001	NS	NS	NS	NS
h.b.	NS	NS	NS	NS	NS	N
h.b.1.	NS	NS	NS	NS	NS	NS
l.r.						
a.r.h.	NS	<.001	<.001	NS	NS	NS
p.r.h.	NS	<.001	<.001	NS	NS	N
r.MD	<.001	<.001	NS	NS	NS	NS
r.r.	<.001	<.01	NS	NS	NS	NS
r.ang	NS	NS	NS	NS	NS	NS

F (1) : The pongids

	t-test			F-ratio		
	Gorilla /Pongo	Gorilla /Pan	Pan/ Pongo	Gorilla /Pongo	Gorilla /Pan	Pan/ Pongo
mb.r.						
a.r.h.	NS	.001	<.001	NS	NS	NS
p.r.h.	NS	.001	<.001	NS	NS	NS
r.MD	<.001	<.001	<.01	<.01	NS	NS
r.r.	<.001	NS	NS	NS	NS	NS
r.ang	NS	NS	NS	NS	NS	NS
db.r.						
a.r.h.	NS	<.001	<.001	NS	NS	NS
p.r.h.	NS	.001	<.001	NS	NS	NS
r.MD	NS	<.001	.001	NS	NS	NS
r.r.	NS	NS	NS	NS	NS	NS
r.ang	NS	NS	NS	NS	NS	NS
r.div	NS	NS	NS	<.01	NS	NS
c.MD	<.001	<.001	<.001	NS	NS	NS
c.BL	<.001	<.001	<.001	NS	<.01	NS
M_1						
l.b.	<.001	<.001	<.001	NS	<.001	NS
h.b.	.001	NS	<.001	NS	NS	NS
h.b.1.	<.001	<.001	NS	NS	NS	NS
l.r.						
a.r.h.	<.001	<.001	<.001	NS	NS	NS
p.r.h.	<.001	<.001	<.001	NS	NS	NS
r.MD	<.001	<.001	<.001	<.01	.001	NS
r.r.	<.001	<.001	NS	NS	NS	NS
r.ang	NS	NS	NS	NS	NS	NS
mb.r.						
a.r.h.	NS	<.001	<.001	NS	NS	NS
p.r.h.	NS	<.001	<.001	NS	NS	NS
r.MD	<.001	<.001	<.001	NS	NS	NS
r.r.	<.001	NS	<.001	NS	NS	NS
r.ang	NS	<.001	<.001	NS	NS	NS
db.r.						
a.r.h.	NS	<.001	<.001	NS	NS	NS
p.r.h.	NS	<.001	<.001	NS	NS	NS
r.MD	<.001	<.001	<.01	NS	NS	NS
r.r.	<.001	NS	<.001	NS	NS	NS

F (1) : The pongids

	t-test			F-ratio		
	Gorilla /Pongo	Gorilla /Pan	Pan/ Pongo	Gorilla /Pongo	Gorilla /Pan	Pan/ Pongo
r.ang	NS	NS	NS	NS	NS	NS
r.div	<.001	NS	<.001	NS	NS	NS
c.MD	<.001	<.001	<.001	NS	NS	NS
c.BL	<.001	<.001	<.001	NS	<.001	NS
M^2						
l.b.	<.001	<.001	<.001	NS	NS	NS
h.b.	NS	NS	<.01	NS	NS	NS
h.b.1.	.001	<.001	NS	NS	NS	<.01
l.r.						
a.r.h.	NS	<.001	<.001	NS	NS	<.01
p.r.h.	<.01	<.001	<.001	NS	NS	<.01
r.MD	<.001	<.001	<.001	.001	<.001	NS
r.r.	<.001	<.001	NS	NS	NS	NS
r.ang	<.01	NS	<.01	NS	NS	NS
mb.r.						
a.r.h.	NS	<.001	<.001	NS	NS	NS
p.r.h.	NS	<.001	<.001	NS	NS	NS
r.MD	<.001	<.001	<.001	<.001	NS	NS
r.r.	NS	NS	<.01	NS	NS	NS
r.ang	NS	.01	<.01	NS	NS	NS
db.r.						
a.r.h.	NS	<.001	<.001	NS	NS	NS
p.r.h.	NS	<.001	<.001	NS	NS	NS
r.MD	<.001	<.001	<.001	NS	<.001	NS
r.r.	<.001	NS	NS	NS	NS	NS
r.ang	NS	.001	NS	NS	NS	NS
r.div	NS	<.001	.001	NS	NS	NS
c.MD	<.001	<.001	<.001	NS	<.01	NS
c.BL	<.001	<.001	<.001	NS	<.01	NS
M^3						
l.b.	<.001	<.001	<.001	NS	NS	NS
h.b.	NS	NS	NS	NS	NS	NS
h.b.1.	NS	<.001	<.01	NS	NS	NS
l.r.						
a.r.h.	NS	<.001	<.001	NS	<.01	.001
p.r.h.	NS	<.001	<.001	NS	<.01	<.01

F (1) : The pongids

	t-test			F-ratio		
	Gorilla /Pongo	Gorilla /Pan	Pan/ Pongo	Gorilla /Pongo	Gorilla /Pan	Pan/ Pongo
r.MD	<.001	<.001	<.001	NS	<.001	NS
r.r.	<.001	<.001	<.01	NS	NS	NS
r.ang	NS	NS	.001	NS	NS	NS
mb.r.						
a.r.h.	NS	<.001	<.001	NS	.001	NS
p.r.h.	NS	<.001	<.001	NS	.001	NS
r.MD	<.001	<.001	<.001	NS	NS	NS
r.r.	NS	NS	<.05	NS	NS	NS
r.ang	NS	<.001	NS	NS	NS	NS
db.r.						
a.r.h.	NS	<.001	<.001	NS	<.01	NS
p.r.h.	NS	<.001	<.001	NS	<.01	NS
r.MD	NS	<.001	<.001	NS	<.01	NS
r.r.	NS	NS	NS	NS	NS	NS
r.ang	<.001	NS	NS	NS	NS	NS
r.div	<.001	.001	NS	NS	<.01	NS
c.MD	<.001	<.001	<.001	NS	<.01	NS
c.BL	<.001	<.001	<.001	NS	<.001	NS
Jaw						
p.l.	<.001	<.001	.001	.001	<.001	NS
p.b.	<.01	<.001	<.001	NS	.001	<.01
m.l.	<.001	<.001	<.001	NS	<.001	NS
m.d.$C_{\overline{1}}$	NS	<.001	<.001	NS	<.01	<.01
m.d.$M_{\overline{1}}$	NS	<.001	<.001	NS	<.01	.001
m.d.$M_{\overline{2}}$	NS	<.001	<.001	NS	NS	<.01
m.d.$M_{\overline{3}}$	NS	<.001	<.001	NS	<.01	<.01

F (11) : H.sapiens/the pongids

	t-test			F-ratio		
	H.sapiens /Pan	H.sapiens /Pongo	H.sapiens /Gorilla	H.sapiens /Pan	H.sapiens /Pongo	H.sa ie /Gori l
I_1						
n.MD	<.001	<.001	<.001	NS	NS	NS
a.r.h.	<.001	<.001	<.001	NS	NS	NS
p.r.h.	<.001	<.001	<.001	NS	NS	NS
r.ang	<.001	<.001	<.01	NS	NS	NS
c.MD	<.001	<.001	<.001	NS	<.01	<.01
c.BL	<.001	<.001	<.001	NS	<.01	<.01
I_2						
n.MD	<.001	<.001	<.001	NS	NS	NS
a.r.h	<.001	<.001	<.001	NS	NS	NS
p.r.h	<.001	<.001	<.001	NS	NS	NS
r.ang	<.001	<.001	<.001	NS	NS	NS
c.MD	<.001	<.001	<.001	NS	NS	NS
c.BL	<.001	<.001	<.001	NS	<.01	<.001
C_1						
n.MD	<.001	<.001	<.001	<.001	<.001	<.001
a.r.h	<.001	<.001	<.001	NS	<.001	NS
r.MD	<.001	<.001	<.001	NS	<.01	<.001
r.r.	NS	<.01	NS	NS	NS	NS
c.MD	<.001	<.001	<.001	<.001	<.001	<.001
c.BL	<.001	<.001	<.001	<.001	<.001	<.001
P_3						
n.MD	<.001	<.001	<.001	NS	<.001	<.001
a.r.h.	NS	-	-	NS	-	-
p.r.h.	NS	-	-	NS	-	-
r.MD	<.001	-	-	NS	-	-
r.r.	<.001	-	-	NS	-	-
r.ang	NS	-	-	<.01	-	-
c.MD	<.001	<.001	<.001	NS	NS	<.01
c.BL	<.001	<.001	<.001	NS	.001	<.001
P_4						
n.MD	<.001	<.001	<.001	NS	NS	<.01
c.MD	<.001	<.001	<.001	Ns	NS	NS
c.BL	<.01	<.001	<.001	NS	NS	NS
M_1						
n.MD	NS	<.001	<.001	NS	NS	NS

F (11) : H.sapiens/the pongids

	t-test			F-ratio		
	H.sapiens /Pan	H.sapiens /Pongo	H.sapiens /Gorilla	H.sapiens /Pan	H.sapiens /Pongo	H.sapiens /Gorilla
l.b.	NS	<.001	<.001	NS	NS	NS
l.b.i.	NS	<.01	<.001	NS	NS	NS
h.b.	<.001	NS	<.001	NS	NS	NS
h.b.i.	<.001	<.001	<.001	NS	NS	NS
m.r.						
a.r.h.	<.01	<.001	<.001	NS	<.01	NS
p.r.h.	<.01	<.001	<.001	NS	<.01	NS
r.MD	NS	NS	<.001	NS	NS	NS
r.r.	<.01	<.001	NS	NS	NS	NS
r.ang	NS	NS	NS	NS	NS	NS
d.r.						
a.r.h.	NS	<.001	<.001	NS	<.001	<.01
p.r.h.	NS	<.001	<.001	NS	<.001	<.01
r.MD	<.001	<.001	<.001	NS	NS	NS
r.r.	<.001	<.001	<.001	NS	NS	NS
r.ang	NS	NS	<.001	NS	NS	<.01
r.div	NS	NS	<.001	NS	NS	NS
c.MD	NS	<.001	<.001	NS	NS	NS
c.BI	<.001	<.001	<.001	NS	NS	NS
M_2						
n.MD	<.001	<.001	<.001	<.01	NS	NS
l.b.	<.01	<.001	<.001	NS	NS	NS
l.b.i.	NS	NS	<.01	NS	NS	NS
h.b.	<.001	NS	NS	NS	NS	NS
h.b.i.	.001	<.001	<.001	NS	NS	NS
m.r.						
a.r.h.	NS	<.001	<.001	NS	<.01	NS
p.r.h.	NS	<.001	<.001	NS	<.01	NS
r.MD	<.001	<.001	<.001	NS	<.01	.001
r.r.	<.001	NS	<.01	NS	NS	NS
r.ang	<.001	<.001	<.001	NS	NS	NS
d.r.						
a.r.h.	NS	<.001	<.001	NS	.001	NS
p.r.h.	NS	<.001	<.001	NS	.001	NS
r.MD	<.01	<.001	<.001	NS	NS	NS

F (11) : H.sapiens/the pongids

	t-test			F-ratio		
	H.sapiens /Pan	H.sapiens /Pongo	H.sapiens /Gorilla	H.sapiens /Pan	H.sapiens /Pongo	H.sapiens /Gorilla
r.r.	.001	NS	<.001	NS	NS	NS
r.ang	NS	NS	<.001	NS	NS	NS
r.div	<.001	<.001	<.001	NS	NS	NS
c.MD	NS	<.001	<.001	.001	NS	NS
c.BL	NS	<.001	<.001	NS	NS	NS
M_3						
n.MD	NS	<.001	<.001	NS	NS	NS
l.b.	NS	<.001	<.001	NS	NS	NS
l.b.a.	NS	NS	<.01	NS	NS	NS
h.b.	<.001	NS	<.01	NS	NS	NS
h.b.a.	NS	<.001	<.001	NS	NS	NS
m.r.						
a.r.h.	<.001	<.001	<.001	NS	NS	NS
p.r.h.	<.001	<.001	<.001	NS	NS	NS
r.MD	NS	<.001	<.001	NS	NS	NS
r.r.	<.001	<.01	NS	NS	NS	NS
r.ang	<.001	<.01	<.01	NS	NS	<.01
d.r.						
a.r.h.	<.001	<.001	<.001	NS	<.01	NS
p.r.h.	<.001	<.001	<.001	NS	<.01	NS
r.MD	NS	<.001	<.001	NS	NS	NS
r.r.	<.001	NS	<.001	NS	<.01	NS
r.ang	<.001	<.001	<.001	NS	NS	NS
r.div	<.001	<.001	<.001	NS	NS	NS
c.MD	NS	<.001	<.001	NS	NS	NS
c.BL	NS	<.001	<.001	<.01	NS	NS
I^1						
n.MD	<.001	<.001	<.001	NS	<.01	.001
a.r.h.	<.001	<.001	<.001	NS	NS	.001
p.r.h.	<.001	<.001	<.001	NS	NS	.001
r.ang	NS	NS	NS	NS	NS	NS
c.MD	<.001	<.001	<.001	NS	<.01	<.01
c.BL	<.001	<.001	<.001	NS	<.01	NS
I^2						
n.MD	<.001	<.001	<.001	NS	NS	NS
a.r.h.	<.001	<.001	<.001	NS	NS	NS

F (11) : H.sapiens/the pongids

	t-test			F-ratio		
	H.sapiens /Pan	H.sapiens /Pongo	H.sapiens /Gorilla	H.sapiens /Pan	H.sapiens /Pongo	H.sapiens /Gorill
p.r.h.	<.001	<.001	<.001	NS	NS	NS
r.ang	NS	NS	NS	NS	NS	.001
c.MD	<.001	<.001	<.001	NS	<.01	NS
c.BL	<.001	<.001	<.001	NS	NS	.001
p^3						
c.MD	<.001	<.001	<.001	NS	NS	NS
c.BL	<.001	<.001	<.001	NS	NS	NS
p^4						
c.MD	<.001	<.001	<.001	NS	NS	NS
c.BL	<.001	<.001	<.001	NS	NS	NS
M^1						
l.b.	<.01	<.001	<.001	NS	NS	NS
h.b.	<.001	NS	<.001	NS	NS	NS
h.b.i.	<.001	<.001	<.001	NS	NS	NS
l.r.						
a.r.h.	NS	<.001	<.001	NS	NS	NS
p.r.h.	NS	<.001	<.001	NS	NS	NS
r.MD	NS	<.001	<.001	NS	NS	<.01
r.r.	NS	<.001	<.001	NS	NS	<.01
r.ang	NS	NS	NS	NS	<.01	<.01
mb.r.						
a.r.h.	.001	<.001	<.001	NS	<.01	<.01
p.r.h.	.001	<.001	<.001	NS	<.01	<.01
r.MD	NS	<.001	<.001	NS	NS	NS
r.r.	<.01	<.01	NS	NS	NS	NS
r.ang	<.01	<.001	NS	NS	<.01	.001
db.r.						
a.r.h.	NS	<.001	<.001	NS	NS	<.01
p.r.h.	NS	<.001	<.001	NS	NS	NS
r.MD	NS	<.001	<.001	NS	NS	<.01
r.r.	NS	NS	<.01	NS	NS	NS
r.ang	NS	NS	.001	NS	NS	NS
r.div	.001	<.01	NS	NS	NS	NS
c.MD	NS	<.001	<.001	NS	NS	NS
c.BL	NS	<.001	<.001	.001	NS	NS
M^2						
l.b.	.001	<.01	<.001	NS	NS	<.01

F (11) : H.sapiens/the pongids

	t-test			F-ratio		
	H.sapiens /Pan	H.sapiens /Pongo	H.sapiens /Gorilla	H.sapiens /Pan	H.sapiens /Pongo	H.sapien /Gorill
h.b.	<.001	<.01	<.001	NS	NS	NS
h.b.i.	<.001	<.001	<.001	NS	<.01	NS
l.r.						
a.r.h.	NS	<.001	<.001	NS	NS	NS
p.r.h.	NS	<.001	<.001	NS	NS	NS
r.MD	<.001	<.001	<.001	NS	NS	<.001
r.r.	<.001	<.001	<.001	NS	NS	.001
r.ang	NS	NS	NS	NS	NS	NS
mb.r.						
a.r.h.	<.001	<.001	<.001	NS	.001	<.001
p.r.h.	.001	<.001	<.001	NS	<.01	.001
r.MD	NS	<.001	<.001	NS	NS	<.01
r.r.	<.001	NS	<.001	NS	NS	NS
r.ang	<.001	NS	<.01	NS	NS	NS
db.r.						
a.r.h.	<.01	<.001	<.001	NS	<.01	.001
p.r.h.	<.01	<.001	<.001	NS	NS	<.01
r.MD	NS	<.001	<.001	NS	NS	<.01
r.r.	NS	NS	<.001	NS	NS	<.001
r.ang	NS	NS	<.001	<.01	NS	NS
r.div	<.001	NS	NS	NS	NS	NS
c.MD	NS	<.001	<.001	<.01	NS	NS
c.BL	NS	<.001	<.001	<.001	NS	NS
M^3						
l.b.	<.01	NS	<.001	<.01	NS	NS
h.b.	<.001	<.01	<.01	NS	NS	NS
h.b.i.	NS	<.001	<.001	NS	NS	NS
l.r.						
a.r.h.	NS	<.01	<.001	NS	NS	NS
p.r.h.	<.01	NS	<.001	NS	NS	NS
r.MD	NS	<.001	<.001	NS	NS	NS
r.r.	<.01	<.001	<.001	NS	NS	NS
i.ang	NS	<.001	NS	NS	NS	NS
mb.r.						
a.r.h.	<.01	NS	NS	NS	NS	NS
p.r.h.	NS	NS	<.01	NS	NS	NS

F (11) : H.sapiens/the pongids

	t-test			F-ratio		
	H.sapiens /Pan	H.sapiens /Pongo	H.sapiens /Gorilla	H.sapiens /Pan	H.sapiens /Pongo	H.sapien /Gorill
r.MD	NS	NS	<.001	NS	NS	NS
r.r.	.01	NS	NS	NS	NS	NS
r.ang	<.001	<.01	NS	NS	NS	NS
db.r.						
a.r.h.	<.001	NS	NS	NS	NS	NS
p.r.h.	.001	NS	.01	NS	NS	NS
r.MD	NS	<.001	<.001	NS	NS	NS
r.r.	.01	NS	<.001	NS	NS	NS
r.ang	NS	NS	NS	NS	NS	NS
r.div	<.01	<.001	NS	NS	NS	NS
c.MD	<.01	<.001	<.001	NS	NS	NS
c.BI	NS	<.001	<.001	<.001	<.001	NS
Jaw						
p.l.	<.001	<.001	<.001	NS	NS	<.001
p.b.	NS	<.001	<.001	.001	NS	NS
m.l.	<.001	<.001	<.001	NS	NS	<.01
m.d.$C_{\overline{1}}$	<.001	<.001	<.001	NS	<.01	NS
m.d.$M_{\overline{1}}$	NS	<.001	<.001	NS	<.01	NS
m.d.$M_{\overline{2}}$	NS	<.001	<.001	NS	<.01	NS
m.d.$M_{\overline{3}}$	NS	<.001	<.001	NS	<.01	.01

F (111) : Romano-British/Australian Aborigines

	t-test	F-ratio		t-test	F-ratio
I_1			h.b.	NS	NS
n.MD	<.001	NS	m.r.		
a.r.h.	<.05	NS	a.r.h.	<.05	NS
p.r.h.	<.05	NS	p.r.h.	NS	NS
r.ang	NS	NS	r.MD	NS	<.01
c.MD	NS	<.05	r.ang	<.01	NS
c.BL	<.05	NS	d.r.		
I_2			a.r.h.	<.05	NS
n.MD	<.001	NS	p.r.h.	<.05	NS
a.r.h.	NS	NS	r.MD	NS	NS
p.r.h.	NS	<.05	r.ang	NS	NS
r.ang	NS	NS	c.MD	<.001	NS
c.MD	NS	<.01	c.BL	<.001	NS
c.BL	.001	NS	M_2		
C_1			n.MD	<.001	NS
n.MD	<.01	NS	l.b.	<.001	NS
a.r.h.	.001	NS	h.b.	NS	NS
r.MD	NS	NS	m.r.		
c.MD	<.001	NS	a.r.h.	<.01	NS
c.BL	<.001	NS	p.r.h.	<.01	NS
P_3			r.MD	NS	NS
n.MD	.001	<.05	r.ang	NS	NS
a.r.h.	.01	NS	d.r.		
p.r.h.	<.05	NS	a.r.h.	<.01	NS
r.MD	<.05	<.05	p.r.h.	<.01	NS
r.ang	<.05	NS	r.MD	NS	NS
c.MD	<.001	NS	r.ang	NS	NS
c.BL	<.001	NS	c.MD	<.001	NS
P_4			c.BL	<.001	NS
n.MD	<.001	NS	M_3		
a.r.h.	NS	NS	n.MD	<.001	NS
p.r.h.	NS	NS	l.b.	<.001	NS
r.MD	NS	<.01	h.b.	<.05	NS
r.ang	NS	NS	m.r.		
c.MD	<.001	NS	a.r.h.	NS	NS
c.BL	<.001	NS	p.r.h.	<.05	NS
M_1			r.MD	NS	NS
n.MD	<.001	NS	r.ang	NS	NS
l.b.	<.01	<.05			

F (111) : Romano-British/Australian Aborigines

	t-test	F-ratio		t-test	F-ratio
d.r.			l.r.		
a.r.h.	<.05	NS	a.r.h.	NS	<.01
p.r.h.	<.01	NS	p.r.h.	NS	<.01
r.MD	<.05	NS	r.MD	<.05	NS
r.ang	NS	NS	r.ang	<.05	NS
c.MD	<.001	NS	mb.r.		
c.BL	<.001	NS	a.r.h.	NS	NS
I^1			p.r.h.	NS	NS
n.MD	<.01	NS	r.MD	NS	<.05
a.r.h.	<.05	NS	r.ang	<.05	NS
p.r.h.	<.05	NS	db.r.		
r.ang	NS	NS	a.r.h.	NS	NS
c.MD	NS	NS	p.r.h.	NS	NS
c.BL	<.001	NS	r.MD	NS	NS
I^2			r.ang	NS	<.05
n.MD	<.001	NS	c.MD	<.001	NS
a.r.h.	<.01	<.001	c.BL	<.001	NS
p.r.h.	<.01	NS	M^2		
r.ang	NS	NS	l.b.	NS	NS
c.MD	<.001	NS	h.b.	NS	NS
c.BL	<.001	NS	l.r.		
P^3			a.r.h.	NS	NS
a.r.h.	<.001	NS	p.r.h.	NS	NS
p.r.h.	<.001	NS	r.MD	<.05	NS
r.MD	.001	NS	r.ang	NS	NS
r.ang	NS	NS	mb.r.		
c.MD	<.001	NS	a.r.h.	<.001	NS
c.BL	<.001	NS	p.r.h.	<.001	NS
P^4			r.MD	NS	NS
a.r.h.	.001	NS	r.ang	NS	<.05
p.r.h.	.001	NS	db.r.		
r.MD	<.05	NS	a.r.h.	<.01	<.05
r.ang	<.01	NS	p.r.h.	<.01	<.05
c.MD	<.001	NS	r.MD	NS	NS
c.BL	<.001	NS	r.ang	NS	NS
M^1			c.MD	<.001	NS
l.b.	<.01	NS	c.BL	<.001	NS
h.b.	NS	NS			

F (111) : Romano-British/Australian Aborigines

	t-test	F-ratio		t-test	F-ratio
M^3			p.r.h.	-	-
l.b.	-	-	r.MD	-	-
h.b.	-	-	r.ang	-	-
l.r.			c.MD	<.001	NS
a.r.h.	-	-	c.BL	<.001	NS
p.r.h.	-	-			
r.MD	-	-	Jaw		
r.ang	-	-	p.l.	<.001	NS
mb.r.			p.b.	<.01	NS
a.r.h.	-	-	m.l.	<.001	NS
p.r.h.	-	-	m.d.C_{-1}	NS	NS
r.MD	-	-	m,d.M_{-1}	NS	NS
r.ang	-	-	m.d.M_{-2}	NS	NS
db.r.			m.d.M_{-3}	<.05	NS
a.r.h.	-	-			

Appendix G : Statistical summaries for the root, crown and jaw dimensions in the males and females of each comparative sample

G (i) : Neck mesiodistal diameter

G (ii) : Location of bifurcation

G (iii) : Actual root height

G (iv) : Projected root height

G (v) : Root mesiodistal diameter

G (vi) : Height of bifurcation

G (vii) : Root angulation

G (viii) : Crown mesiodistal diameter

G (ix) : Crown buccolingual diameter

G (x) : Jaw dimensions

	Male							Female							P	
	X	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t	F
I_1																	
Gorilla	5.5	0.11	0.4	4.8	6.3	8.0	17	5.2	0.15	0.5	4.1	5.8	10.3	13	95	NS	NS
Pan	5.1	0.13	0.5	4.3	6.2	10.5	17	5.1	0.09	0.3	4.7	5.5	5.3	9	100	NS	NS
Pongo	6.0	0.13	0.5	5.2	7.0	8.8	16	5.6	0.11	0.4	4.8	6.4	7.6	15	93	<.05	NS
H.sapiens(pooled)	3.5	0.15	0.5	2.7	4.3	14.7	11	3.5	0.12	0.4	2.9	4.4	12.6	14	100	NS	NS
Romano-British	3.2	0.10	0.3	2.7	3.7	8.7	8	3.2	0.07	0.2	2.9	3.5	6.0	9	100	NS	NS
Aust.Aborigines	4.1	-	-	3.7	4.3	-	3	3.9	0.18	0.4	3.5	4.4	9.9	5	95	-	-
I_2																	
Gorilla	6.3	0.12	0.5	5.4	7.6	8.7	20	5.5	0.17	0.7	4.2	6.8	12.2	16	87	.001	NS
Pan	5.5	0.16	0.6	4.6	7.0	11.5	17	5.5	0.10	0.3	5.1	6.1	5.3	9	100	NS	<.05
Pongo	6.0	0.17	0.7	5.2	8.0	11.7	17	5.9	0.16	0.6	5.2	6.9	10.2	14	98	NS	NS
H.sapiens(pooled)	4.1	0.17	0.6	3.2	5.6	15.5	14	4.0	0.15	0.6	3.1	5.1	15.4	16	98	NS	NS
Romano-British	3.8	0.12	0.4	3.2	4.3	10.1	10	3.6	0.11	0.4	3.1	4.4	9.8	10	95	NS	NS
Aust.Aborigines	4.8	-	-	4.1	5.6	-	4	4.6	0.20	0.5	3.9	5.1	10.6	6	96	-	-
C_1																	
Gorilla	14.4	0.38	1.6	12.3	19.1	11.3	19	9.7	0.28	0.9	8.7	11.5	8.7	14	67	<.001	<.05
Pan	11.4	0.30	1.3	8.3	13.2	11.3	19	8.9	0.28	0.9	7.2	11.2	10.5	11	78	<.001	NS
Pongo	12.4	0.25	1.0	10.6	14.1	7.8	15	9.8	0.37	1.4	8.0	12.3	14.1	14	79	<.001	NS
H.sapiens(pooled)	6.7	0.23	0.8	4.9	8.2	12.6	14	6.3	0.20	0.8	4.8	8.2	12.9	17	94	NS	NS
Romano-British	6.4	0.25	0.8	4.9	7.2	11.8	9	5.9	0.22	0.7	4.8	6.9	12.0	10	92	NS	NS
Aust.Aborigines	7.3	0.30	0.7	6.8	8.2	9.2	5	6.8	0.24	0.6	6.3	8.2	9.4	7	93	NS	NS

	Males							Females								P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t	F
P_3																	
Gorilla	14.6	0.23	1.1	12.8	16.8	7.6	23	12.6	0.27	1.1	11.1	14.3	8.9	17	86	<.001	NS
Pan	8.8	0.25	1.1	6.6	11.5	12.8	20	8.3	0.21	0.7	6.6	9.3	8.5	11	94	NS	NS
Pongo	12.5	0.29	1.3	10.2	15.1	10.2	19	10.8	0.22	0.8	9.1	12.1	7.7	15	86	<.001	NS
H.sapiens(pooled	5.4	0.19	0.7	4.2	6.9	13.7	15	5.2	0.14	0.6	4.2	6.1	10.8	17	96	NS	NS
Romano-British	5.0	0.12	0.4	4.2	5.4	7.6	10	4.9	0.12	0.4	4.2	5.5	7.8	10	98	NS	NS
Aust.Aborigines	6.0	0.38	0.9	4.8	6.9	14.2	5	5.6	0.18	0.5	4.7	6.1	8.4	7	93	NS	NS
P_4																	
Gorilla	11.4	0.20	1.0	9.9	14.0	8.4	22	10.7	0.24	1.0	9.1	13.3	9.1	17	94	<.05	NS
Pan	7.4	0.14	0.6	6.3	8.8	8.6	20	7.3	0.23	0.8	6.0	8.6	10.3	11	99	NS	NS
Pongo	10.4	0.18	0.8	8.5	12.0	7.3	19	9.4	0.20	0.8	8.0	10.5	8.1	15	90	<.001	NS
H.sapiens(pooled)	5.5	0.17	0.7	4.6	6.8	11.9	15	5.2	0.12	0.5	4.5	6.1	9.4	18	95	NS	NS
Romano-British	5.2	0.16	0.5	4.6	5.9	9.5	10	4.9	0.10	0.3	4.5	5.5	6.3	10	94	NS	NS
Aust.Aborigines	6.1	0.24	0.5	5.3	6.8	8.7	5	5.5	0.17	0.5	4.8	6.1	8.8	8	90	NS	NS
M_1																	
Gorilla	15.4	0.22	1.1	13.8	17.7	6.8	23	14.0	0.25	1.0	11.9	15.9	7.3	17	91	<.001	NS
Pan	10.0	0.16	0.7	8.5	11.0	7.3	20	9.7	0.11	0.4	9.0	10.2	3.9	11	97	NS	<.05
Pongo	12.4	0.18	0.8	11.0	13.6	6.2	19	11.4	0.16	0.6	10.5	12.7	5.6	15	92	<.001	NS
H.Sapiens(pooled)	10.0	0.22	0.9	8.4	11.7	8.6	16	9.3	0.18	0.8	7.9	10.3	8.1	17	93	<.05	NS
Romano-British	9.5	0.20	0.6	8.4	10.2	6.5	10	8.9	0.22	0.7	7.9	10.0	7.9	10	94	<.05	NS
Aust.Aborigines	10.8	0.24	0.6	10.1	11.7	5.6	6	9.9	0.13	0.3	9.3	10.3	3.5	7	92	<.01	NS

G(1): Neck mesiodistal diameter

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t F
M_2																
Gorilla	16.8	0.21	1.0	15.3	19.1	6.0	23	15.1	0.25	1.1	13.0	17.0	6.9	17	90	<.001 NS
Pan	10.5	0.18	0.8	9.5	13.0	7.9	20	10.2	0.10	0.3	9.4	10.6	3.3	11	97	NS <.01
Pongo	13.2	0.20	0.9	11.6	14.9	6.6	19	12.1	0.20	0.8	10.8	13.3	6.3	15	92	<.001 NS
H.sapiens(pooled)	9.9	0.34	1.4	8.3	12.6	13.9	16	9.1	0.20	0.9	7.7	10.4	9.4	18	92	<.05 NS
Romano-British	9.1	0.21	0.7	8.3	10.1	7.3	10	8.6	0.22	0.7	7.7	9.6	8.0	10	95	NS NS
Aust.Aborigines	11.4	0.40	1.0	9.9	12.6	8.5	6	9.8	0.17	0.5	9.0	10.4	4.9	8	86	<.01 NS
M_3																
Gorilla	16.3	0.25	1.2	14.4	19.7	7.4	23	14.8	0.27	1.1	12.5	16.1	7.3	16	91	<.001 NS
Pan	9.9	0.14	0.7	8.8	11.3	6.6	20	9.3	0.14	0.5	8.8	10.2	4.8	11	94	<.05 NS
Pongo	12.8	0.26	1.1	10.4	14.2	8.7	19	11.7	0.23	0.9	10.1	13.1	7.6	15	91	<.01 NS
H.sapiens(pooled)	9.6	0.28	1.1	8.3	11.8	11.2	15	9.7	0.20	0.7	8.3	10.8	7.6	14	101	NS NS
Romano-British	8.9	0.18	0.5	8.3	10.0	6.1	9	9.2	0.21	0.6	8.3	10.0	6.1	7	103	NS NS
Aust.Aborigines	10.7	0.32	0.8	9.8	11.8	7.4	6	10.2	0.19	0.5	9.4	10.8	4.9	7	95	NS NS
I^1																
Gorilla	10.2	0.19	0.8	8.7	11.4	8.1	18	9.4	0.32	1.2	7.1	11.2	12.3	13	92	<.05 NS
Pan	8.5	0.21	0.9	7.2	10.9	10.0	17	8.5	0.14	0.5	7.8	9.3	5.4	11	100	NS NS
Pongo	10.1	0.26	1.1	8.1	11.7	10.5	17	9.5	0.16	0.5	8.5	10.0	5.7	12	94	NS <.05
H.sapiens(pooled)	6.0	0.16	0.5	5.3	7.0	8.9	12	5.9	0.15	0.5	5.3	7.0	9.1	13	98	NS NS
Romano-British	5.9	0.17	0.5	5.3	7.0	9.0	10	5.6	0.13	0.4	5.3	6.2	6.8	9	95	NS NS
Aust.Aborigines	6.6	-	-	6.5	6.6	-	2	6.5	-	-	6.1	7.0	-	4	99	- -

...ular diameter

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t F
I^2																
Gorilla	7.4	0.25	1.0	5.5	9.6	12.9	15	6.6	0.24	0.8	5.2	7.9	12.1	11	89	<.05 NS
Pan	6.4	0.14	0.6	5.5	7.7	8.5	15	6.2	0.12	0.4	5.8	6.9	5.9	10	97	NS NS
Pongo	6.4	0.15	0.6	5.3	7.7	9.9	18	6.0	0.18	0.6	5.0	6.9	10.4	12	94	NS NS
H.sapiens(pooled)	5.3	0.20	0.8	4.1	6.7	14.0	14	5.1	0.20	0.8	4.0	6.6	15.3	15	96	NS NS
Romano-British	4.9	0.15	0.4	4.1	5.5	9.0	9	4.5	0.10	0.3	4.0	5.0	6.5	8	92	<.05 NS
Aust.Aborigines	6.1	0.24	0.5	5.4	6.7	8.6	5	5.7	0.21	0.6	5.2	6.6	9.8	7	93	NS NS

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t F
$2RP_3$																
Gorilla	7.5	0.18	0.9	5.7	9.1	11.4	23	6.4	0.17	0.7	5.2	7.7	10.7	17	85	<.001 NS
Pan	4.7	0.14	0.5	4.0	6.0	11.6	16	4.6	0.21	0.5	3.8	5.2	11.3	6	98	NS NS
Pongo	6.4	0.19	0.8	4.9	8.5	13.1	19	5.9	0.16	0.6	5.1	7.0	10.1	14	92	NS NS
Aust.Aborigines	3.4	-	-	-	-	-	1	-	-	-	-	-	-	-	-	- -
$2RP_4$																
Gorilla	5.3	0.12	0.6	4.5	6.8	10.5	22	5.0	0.09	0.4	4.3	5.6	7.2	17	94	NS NS
Pan	3.6	0.06	0.3	3.0	4.0	7.3	20	3.5	0.17	0.6	2.8	4.8	15.8	11	97	NS <.01
Pongo	5.0	0.12	0.5	4.2	6.3	10.8	19	4.5	0.11	0.4	3.8	5.0	9.4	15	90	<.01 NS
M_1																
Gorilla	7.1	0.15	0.7	6.2	8.6	9.8	23	6.7	0.17	0.7	5.6	8.0	10.4	17	94	NS NS
Pan	5.0	0.11	0.5	4.2	5.8	9.4	20	4.9	0.13	0.5	4.2	5.9	9.1	11	98	NS NS
Pongo	6.1	0.12	0.5	5.2	6.8	8.3	19	5.6	0.12	0.5	4.7	6.6	8.5	15	92	<.01 NS
H.sapiens(pooled)	5.2	0.10	0.4	4.4	5.7	7.3	16	4.8	0.13	0.6	3.9	5.6	11.5	17	92	<.05 NS
Romano-British	5.1	0.12	0.4	4.4	5.7	7.8	10	4.5	0.16	0.5	3.9	5.3	11.3	10	88	<.01 NS
Aust.Aborigines	5.4	0.11	0.3	4.9	5.6	5.2	6	5.2	0.11	0.3	4.7	5.6	5.8	7	96	NS NS
M_2																
Gorilla	8.0	0.16	0.8	7.0	10.1	9.7	23	7.4	0.18	0.8	6.4	8.6	10.1	17	93	<.05 NS
Pan	5.3	0.09	0.4	4.6	6.2	7.9	20	4.9	0.08	0.3	4.4	5.3	5.2	11	93	<.05 NS
Pongo	6.4	0.12	0.5	5.6	7.2	8.1	19	6.1	0.16	0.6	5.4	7.4	10.3	15	95	NS NNS
H.sapiens(pooled)	5.0	0.17	0.7	3.9	6.3	13.4	16	4.6	0.13	0.5	3.8	5.8	11.4	17	92	NS NS
Romano-British	4.6	0.14	0.4	3.9	5.6	9.3	10	4.4	0.15	0.4	3.8	5.0	10.1	9	96	NS NS
Aust.Aborigines	5.6	0.24	0.6	4.9	6.3	10.6	6	5.0	0.16	0.5	4.2	5.8	9.2	8	89	NS NS

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t F
M_3																
Gorilla	7.9	0.12	0.6	6.5	8.8	7.5	23	7.2	0.18	0.7	5.8	8.2	10.0	16	91	.001 NS
Pan	5.1	0.11	0.5	3.9	5.8	9.3	20	4.8	0.18	0.6	3.7	5.6	12.2	11	94	NS NS
Pongo	6.6	0.13	0.6	5.4	7.4	8.5	19	5.0	0.14	0.5	4.7	6.9	8.9	15	89	.001 NS
H.sapiens(pooled)	5.1	0.18	0.7	4.1	6.0	13.0	14	5.0	0.15	0.6	4.2	6.0	11.5	14	98	NS NS
Romano-British	4.6	0.15	0.4	4.1	5.4	9.3	8	4.6	0.11	0.3	4.2	5.0	6.5	7	100	NS NS
Aust.Aborigines	5.6	0.17	0.4	5.0	6.0	7.6	6	5.4	0.19	0.5	4.6	6.0	9.3	7	96	NS NS
$3RP^3$																
Gorilla	5.7	0.17	0.8	4.8	8.0	13.6	22	5.4	0.11	0.4	4.7	6.2	8.1	17	95	NS <.05
Pan	3.3	0.15	0.6	1.8	4.8	19.3	18	3.5	0.18	0.5	2.9	4.4	15.1	9	106	NS NS
Pongo	4.5	0.17	0.6	3.6	5.5	14.1	14	3.7	0.23	0.7	2.8	5.2	10.3	10	82	<.05 NS
$3RP^4$																
Gorilla	4.5	0.17	0.8	3.1	6.6	18.4	23	4.1	0.18	0.7	3.0	5.4	18.0	17	91	NS NS
Pan	2.7	-	-	2.4	3.2	-	3	2.2	-	-	1.4	2.9	-	2	82	- -
Pongo	3.5	0.23	0.9	1.9	5.8	26.9	16	3.7	0.21	0.7	2.9	5.0	19.1	11	106	NS NS
M^1																
Gorilla	6.2	0.18	0.8	4.9	8.5	13.6	23	5.4	0.16	0.7	4.6	6.7	12.3	17	87	<.01 NS
Pan	3.8	0.09	0.4	3.0	4.6	11.3	20	3.8	0.11	0.4	3.0	4.3	9.6	11	100	NS NS
Pongo	5.1	0.09	0.4	4.5	5.6	7.2	18	5.0	0.23	0.9	4.0	7.2	17.3	14	98	NS <.01
H.sapiens(pooled)	4.2	0.17	0.7	3.1	5.4	15.4	15	4.0	0.14	0.5	3.2	5.0	13.5	16	95	NS NS
Romano-British	3.9	0.14	0.4	3.1	4.8	11.0	10	3.8	0.20	0.6	3.2	5.0	15.0	8	97	NS NS
Aust.Aborigines	4.9	0.27	0.6	4.0	5.4	12.2	5	4.2	0.16	0.4	3.8	4.8	10.4	8	86	<.05 NS

	Males							Females								P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t	F
M^2																	
Gorilla	6.3	0.22	1.0	4.8	9.1	16.1	21	6.0	0.16	0.6	4.7	7.0	10.1	15	95	NS	NS
Pan	3.9	0.13	0.6	2.8	4.9	14.8	20	3.7	0.20	0.7	3.1	5.3	17.5	10	95	NS	NS
Pongo	4.0	0.23	0.9	3.9	7.4	17.5	14	4.8	0.13	0.5	3.7	5.5	10.2	15	98	NS	<.05
H.sapiens(pooled)	4.5	0.14	0.5	3.4	5.3	11.8	15	4.2	0.12	0.4	3.4	4.7	10.7	13	93	NS	NS
Romano-British	4.4	0.13	0.4	3.8	4.9	9.0	9	3.9	0.25	0.6	3.4	4.7	14.3	5	89	NS	NS
Aust.Aborigines	4.5	0.29	0.7	3.4	5.3	15.8	6	4.3	0.10	0.3	3.8	4.6	6.4	8	96	NS	<.05
M^3																	
Gorilla	6.3	0.18	0.9	5.1	8.1	13.5	23	6.1	0.24	0.9	4.7	7.8	14.4	14	97	NS	NS
Pan	3.6	0.12	0.5	2.7	4.9	14.6	20	3.4	0.20	0.6	2.2	4.0	17.9	10	94	NS	NS
Pongo	4.7	0.20	0.7	3.4	6.0	14.9	13	3.9	0.13	0.4	3.4	4.7	11.1	11	83	<.01	NS
H.sapiens(pooled)	5.1	0.60	1.5	3.1	7.3	28.6	6	4.3	0.16	0.4	3.7	4.8	8.8	6	84	NS	<.01
Romano-British	3.6	-	-	3.1	4.0	-	2	4.4	-	-	4.3	4.5	-	2	122	-	-
Aust.Aborigines	5.9	-	-	5.0	7.3	-	4	4.3	-	-	3.7	4.8	-	4	73	-	-

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t	F
I_1																	
Gorilla	22.2	0.74	2.9	18.0	28.8	12.9	15	19.5	0.39	1.4	17.3	22.8	7.2	13	88	<.01	<.05
Pan	16.9	0.44	1.8	13.2	19.1	10.7	17	16.3	0.48	1.4	13.7	18.5	8.8	9	97	NS	NS
Pongo	22.4	0.59	2.4	18.6	27.3	10.6	16	19.8	0.48	1.9	17.2	23.4	9.4	15	88	<.01	NS
H.sapiens(Pooled)	13.5	0.69	2.3	10.9	17.2	16.9	11	12.5	0.30	1.1	10.2	14.3	9.0	14	93	NS	<.05
Romano-British	12.6	0.63	1.8	10.9	15.4	14.2	8	12.2	0.35	1.1	10.2	14.2	8.7	9	97	NS	NS
Aust.Aborigines	16.0	-	-	14.3	17.2	-	3	13.1	0.48	1.1	11.7	14.3	8.2	5	82	-	-
I_2																	
Gorilla	24.0	0.48	2 2	19.5	28.1	9.0	20	20.8	0.31	1.3	17.9	22.4	6.0	16	87	<.001	<.05
Pan	17.6	0.60	2.5	11.9	22.4	13.9	17	17.0	0.62	1.9	13.5	19.7	10.9	9	97	NS	NS
Pongo	23.3	0.59	2.4	19.9	29.3	10.4	17	21.0	0.57	2.1	17.9	25.0	10.1	14	90	.01	NS
H.sapiens(pooled)	15.1	0.44	1.6	12.7	18.9	10.9	14	13.8	0.45	1.8	10.7	18.8	13.0	16	91	NS	NS
Romano-British	14.4	0.34	1.1	12.7	15.9	7.4	10	14.2	0.58	1.8	12.3	18.8	12.9	10	99	NS	NS
Aust.Aborigines	16.8	0.82	-	14.9	18.9	-	4	13.2	0.69	1.7	10.7	16.0	12.9	6	79	-	-
C_1																	
Gorilla	35.9	0.69	2.8	32.2	41.7	7.9	17	29.4	0.61	2.2	24.6	33.0	7.4	13	82	<.001	NS
Pan	31.6	0.69	2.8	25.7	35.9	8.7	16	24.1	0.83	2.7	20.7	30.1	11.4	11	76	<.001	NS
Pongo	40.6	1.63	4.0	36.0	45.2	9.8	6	30.5	1.62	4.0	24.1	36.0	15.9	9	75	.001	NS
H.sapiens(pooled)	19.1	0.85	3.2	15.0	25.5	16.7	14	16.5	0.50	2.1	12.6	19.8	12.4	17	86	<.01	NS
Romano-British	17.3	0.55	1.7	15.0	20.0	9.5	9	15.6	0.60	1.9	12.6	19.3	12.2	10	90	NS	NS
Aust.Aborigines	22.4	1.17	2.6	19.0	25.6	11.7	5	17.8	0.61	1.6	14.8	19.8	9.0	7	80	<.01	NS

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t	F
$2RP_3$ m																	
Gorilla	23.8	0.58	2.8	20.0	29.6	11.6	23	21.1	0.58	2.3	18.2	26.3	11.0	16	89	<.01	NS
Pan	18.3	0.66	2.7	12.5	23.4	14.4	16	17.8	0.98	2.4	13.5	20.2	13.5	6	97	NS	NS
Pongo	26.8	0.60	2.5	23.7	32.4	9.2	17	23.7	1.10	4.0	19.6	33.5	16.7	13	88	<.05	NS
Aust.Aborigines	16.3	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
$2RP_3$ d																	
Gorilla	23.2	0.65	3.1	18.6	32.0	13.3	23	20.2	0.58	2.3	17.2	26.1	11.5	16	87	<.01	NS
Pan	17.7	0.62	2.5	12.2	20.8	14.0	16	17.2	0.71	1.7	13.9	18.6	10.1	6	97	NS	NS
Pongo	25.1	0.71	2.9	20.3	30.9	11.6	17	21.4	1.09	3.9	16.3	33.0	18.3	13	85	<.01	NS
Aust.Aborigines	15.8	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
$1RP_3$																	
Pan	18.4	-	-	15.5	20.6	-	4	16.9	0.67	1.5	15.7	19.4	8.8	5	92	-	-
Pongo	-	-	-	-	-	-	-	25.0	-	-	-	-	-	1	-	-	-
H.sapiens(pooled)	16.2	0.60	2.2	13.5	21.2	13.8	14	15.2	0.39	1.6	12.6	18.5	10.4	17	94	NS	NS
Romano-British	15.1	0.34	1.1	13.5	16.7	7.2	10	15.0	0.58	1.8	12.6	18.5	12.2	10	99	NS	NS
Aust.Aborigines	19.1	-	-	17.2	21.2	-	4	15.6	0.47	1.2	13.2	16.6	7.9	7	82	-	-
$2RP_4$ m																	
Gorilla	21.2	0.41	1.9	17.6	24.3	9.0	22	19.7	0.48	1.9	15.3	23.1	9.5	15	93	<.05	NS
Pan	17.8	0.49	2.2	13.3	23.0	12.4	20	15.8	0.54	1.8	12.4	18.6	11.4	11	89	<.05	NS
Pongo	24.1	0.69	2.9	19.5	29.6	11.8	17	21.5	1.03	4.0	14.8	31.5	18.5	15	89	<.05	NS

	Males						Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t	F
$2RP_{\bar{4}}$ d																	
Gorilla	21.5	0.41	1.9	18.0	25.0	9.0	22	19.9	0.33	1.3	17.3	22.3	6.6	16	93	<.01	NS
Pan	17.3	0.42	1.9	12.8	20.7	10.8	20	15.6	0.45	1.5	12.9	17.8	9.6	11	90	<.05	NS
Pongo	23.2	0.59	2.4	18.6	27.5	10.5	17	20.9	1.00	3.9	15.2	31.8	18.5	15	90	<.05	NS
$1RP_{\bar{4}}$																	
H.sapiens(pooled)	16.8	0.56	2.2	13.3	21.4	13.0	15	15.1	0.41	1.7	12.4	18.6	11.4	18	90	<.05	NS
Romano-British	16.0	0.59	1.9	13.3	19.2	11.6	10	14.7	0.65	2.1	12.4	18.6	14.0	10	92	NS	NS
Aust.Aborigines	18.3	0.93	2.1	15.8	21.4	11.3	5	15.7	0.38	1.1	13.6	17.0	6.9	8	86	.01	NS
$M_{\bar{1}}$ m																	
Gorilla	18.5	0.56	2.7	15.2	24.1	14.5	23	17.6	0.45	1.9	13.0	19.9	10.5	17	95	NS	NS
Pan	13.4	0.31	1.4	11.1	16.0	10.4	20	12.0	0.50	1.7	10.7	15.0	12.0	11	96	NS	NS
Pongo	21.5	0.60	2.6	16.7	25.7	12.2	19	19.2	0.63	2.4	14.7	24.8	12.7	15	89	<.05	NS
H.sapiens(pooled)	15.1	0.43	1.7	13.0	18.9	11.4	16	13.8	0.31	1.3	11.5	15.6	9.4	17	91	<.05	NS
Romano-British	14.5	0.50	1.6	13.0	18.6	10.9	10	13.4	0.48	1.5	11.5	15.6	11.4	10	92	NS	NS
Aust.Aborigines	16.2	0.61	1.5	14.8	18.9	9.3	6	14.2	0.26	0.7	13.2	15.3	4.7	7	88	<.01	NS
$M_{\bar{1}}$ d																	
Gorilla	19.9	0.59	2.8	16.1	27.8	14.1	23	19.3	0.34	1.4	16.6	20.7	7.3	17	97	NS	<.01
Pan	14.5	0.27	1.2	12.3	16.4	8.3	20	13.8	0.43	1.4	11.9	16.2	10.2	11	95	NS	NS
Pongo	21.3	0.66	2.0	17.0	26.8	13.6	19	19.1	0.65	2.5	14.0	25.4	13.2	15	90	<.05	NS
H.sapiens(pooled)	14.3	0.30	1.6	12.1	18.1	11.0	16	13.3	0.23	1.0	11.0	14.6	7.3	17	93	<.05	NS
Romano-British	13.8	0.40	1.3	12.1	16.5	0.2	10	13.0	0.36	1.1	11.0	14.6	8.8	10	94	NS	NS
Aust.Aborigines	15.3	0.69	1.7	13.5	18.1	11.0	6	13.7	0.17	0.5	13.0	14.3	3.4	7	90	NS	<.01

G(iii): Actual root height

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t F
M_2 m																
Gorilla	20.4	0.52	2.5	16.4	26.6	12.2	23	18.4	0.31	1.3	15.6	20.3	6.9	17	90	<.01 <.01
Pan	13.1	0.33	1.5	10.0	15.8	11.3	20	13.0	0.41	1.4	11.0	15.1	10.5	11	99	NS NS
Pongo	21.6	0.60	2.5	17.2	25.7	11.5	17	19.2	0.81	3.0	15.0	26.7	15.7	14	89	<.05 NS
H.sapiens(pooled)	14.8	0.46	1.0	12.3	18.0	12.6	16	13.3	0.37	1.5	10.8	16.1	11.6	17	90	<.05 NS
Romano-British	13.7	0.37	1.2	12.3	15.8	8.6	10	12.7	0.58	1.7	10.8	16.0	13.7	9	93	NS NS
Aust.Aborigines	16.5	0.55	1.4	14.5	18.0	8.2	6	14.0	0.35	1.0	12.6	16.1	7.0	8	85	<.01 NS
M_2 d																
Gorilla	19.5	0.59	2.8	15.6	25.9	14.5	23	17.8	0.26	1.1	16.1	20.0	5.9	16	91	<.05 <.001
Pan	13.1	0.41	1.8	9.5	17.1	14.1	20	12.5	0.41	1.4	10.2	14.7	11.0	11	95	NS NS
Pongo	21.1	0.66	2.6	16.8	24.5	12.2	15	18.4	0.98	3.5	14.6	27.7	19.2	13	87	<.05 NS
H.sapiens(pooled)	14.1	0.47	1.9	11.0	17.2	13.4	16	12.7	0.32	1.3	10.1	15.2	10.5	17	90	<.05 NS
Romano-British	13.1	0.40	1.3	11.0	15.6	9.8	10	12.1	0.50	1.5	10.1	15.2	12.5	9	92	NS NS
Aust.Aborigines	15.8	0.64	1.6	13.4	17.2	9.9	6	13.4	0.24	0.7	12.6	14.6	5.1	8	85	<.01 NS
M_3 m																
Gorilla	17.7	0.53	2.5	12.7	24.4	14.1	22	15.4	0.31	1.2	13.1	17.4	7.7	15	87	.001 <.01
Pan	10.8	0.28	1.3	8.8	13.3	11.8	20	10.2	0.44	1.5	8.3	12.8	14.2	11	94	NS NS
Pongo	18.8	0.73	2.6	13.7	22.2	14.0	13	15.6	0.70	1.8	13.0	17.9	11.8	7	83	.01 NS
H.sapiens(pooled)	12.7	0.52	1.9	10.6	17.2	14.9	13	12.9	0.49	1.8	10.6	15.8	14.1	14	102	NS NS
Romano-British	11.7	0.29	0.8	10.6	12.9	7.1	8	13.0	0.78	2.1	10.6	15.1	15.9	7	111	NS <.05
Aust.Aborigines	14.2	0.95	2.1	12.0	17.2	14.9	5	12.9	0.64	1.7	11.2	15.8	13.2	7	91	NS NS

G(111): Actual root height

	Males						Females						P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t	F
$M_{\overline{3}}$ d																	
Gorilla	15.3	0.59	2.6	11.1	20.3	16.8	19	13.3	0.32	1.2	10.8	15.0	8.7	13	87	<.01	<.01
Pan	10.1	0.35	1.5	7.8	14.3	15.1	19	9.8	0.44	1.4	8.0	12.3	14.3	10	97	NS	NS
Pongo	17.5	0.85	2.9	12.3	22.0	16.8	12	14.1	0.57	1.5	11.4	16.0	10.8	7	81	<.05	NS
H.sapiens(pooled)	11.6	0.48	1.7	9.6	15.1	14.8	13	11.9	0.38	1.4	9.5	14.5	11.9	14	103	NS	NS
Romano-British	10.7	0.31	0.9	9.6	12.0	8.1	8	11.6	0.59	1.6	9.5	13.6	13.4	7	108	NS	NS
Aust.Aborigines	13.0	0.82	1.8	11.1	15.1	14.1	5	12.1	0.49	1.3	10.9	14.5	10.8	7	93	NS	NS
$I_{\overline{1}}^{1}$																	
Gorilla	23.9	0.78	3.3	19.2	31.5	13.8	18	20.9	0.42	1.5	17.7	22.7	7.2	13	88	<.01	<.01
Pan	19.2	0.61	2.5	13.5	23.7	13.0	17	19.5	0.40	1.3	17.6	21.3	6.7	11	102	NS	<.05
Pongo	21.6	0.45	1.9	18.3	24.3	8.6	17	20.2	0.82	2.9	15.8	28.2	14.1	12	94	NS	NS
H.sapiens(pooled)	13.1	0.42	1.5	11.1	16.1	11.0	12	12.6	0.44	1.6	9.8	16.0	12.6	13	96	NS	NS
Romano-British	12.7	0.35	1.1	11.1	14.5	8.6	10	12.2	0.45	1.4	9.8	14.4	11.1	9	96	NS	NS
Aust.Aborigines	15.3	-	-	14.4	16.1	-	2	13.4	-	-	11.5	16.0	-	4	88	-	-
$I_{\overline{2}}^{2}$																	
Gorilla	23.9	0.68	2.5	19.4	28.5	10.6	14	20.5	0.62	2.1	16.4	23.8	10.1	11	86	<.01	NS
Pan	17.7	0.64	2.4	13.9	22.4	13.6	14	17.4	0.57	1.8	15.2	20.6	10.3	10	98	NS	NS
Pongo	21.4	0.60	2.6	16.7	24.8	11.9	18	19.9	0.83	2.9	15.4	27.5	14.5	12	93	NS	NS
H.sapiens(pooled)	13.9	0.73	2.7	11.3	21.2	19.6	14	12.7	0.40	1.6	10.7	15.5	12.2	15	91	NS	<.05
Romano-British	12.3	0.25	0.8	11.3	13.5	6.1	9	12.0	0.34	1.0	10.7	13.4	7.9	8	98	NS	NS
Aust.Aborigines	16.7	1.25	2.8	14.1	21.2	16.7	5	13.5	0.67	1.8	11.1	15.5	13.2	7	81	<.05	NS

Table 7: Actual root height

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t F
$3RP^3$ l																
Gorilla	20.2	0.60	2.8	14.1	27.8	14.0	22	18,1	0.64	2.6	12.5	24.1	14.6	17	90	<.05 NS
Pan	14.1	0.38	1.6	11.1	16.9	11.4	18	13.2	0.43	1.3	10.8	14.6	9.7	9	94	NS NS
Pongo	20.2	0.68	2.5	16.6	23.8	12.6	14	19.0	0.58	1.8	16.1	22.5	9.7	10	94	NS NS
$3RP^3$ mb																
Gorilla	24.1	0.90	4.2	16.6	33.0	17.4	22	20.6	0.82	3.4	15.9	27.3	16.5	17	86	<.01 NS
Pan	14.7	0.55	2.3	12.0	18.8	15.8	18	13.7	0.90	2.7	9.0	17.7	19.7	9	93	NS NS
Pongo	21.8	0.62	2.3	17.6	24.8	10.6	14	20.6	1.12	3.5	15.8	27.4	17.1	10	95	NS NS
$3RP^3$ db																
Gorilla	19.2	0.77	3.6	13.8	25.9	18.7	22	16.9	0.83	3.4	12.9	25.6	20.3	17	88	NS NS
Pan	12.3	0.45	1.9	8.9	16.7	15.6	18	11.8	0.55	1.7	8.5	14.5	14.0	9	96	NS NS
Pongo	18.4	0.52	2.0	15.2	21.2	10.6	14	17.6	1.04	3.3	13.7	22.9	18.8	10	96	NS NS
$2RP^3$ l																
Pan	13.6	-	-	-	-	-	1	12.9	-	-	12.6	13.8	-	2	-	- -
Pongo	-	-	-	-	-	-	-	18.8	-	-	17.2	20.4	-	2	-	- -
H.sapiens(pooled)	12.8	-	-	11.1	13.8	-	4	14.9	-	-	-	-	-	1	-	- -
Romano-British	12.7	-	-	11.1	13.8	-	3	-	-	-	-	-	-	-	-	- -
Aust.Aborigines	13.2	-	-	-	-	-	1	14.9	-	-	-	-	-	1	-	- -
$2RP^3$ b																
Pan	15.0	-	-	-	-	-	1	14.2	-	-	13.2	15.1	-	2	-	- -
Pongo	-	-	-	-	-	-	-	21.7	-	-	20,2	23.2	-	2	-	- -
H.sapiens(pooled)	13.6	-	-	12.2	15.2	-	4	16.6	-	-	-	-	-	1	-	- -
Romano-British	13.1	-	-	12.2	14.0	-	3	-	-	-	-	-	-	-	-	- -
Aust.Aborigines	15.2	-	-	-	-	-	1	16.6	-	-	-	-	-	1	-	- -

	Males							Females							P		
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t	F
1RP^3																	
H.sapiens(pooled)	16.7	0.92	3.2	13.2	23.1	19.0	12	15.2	0.60	2.3	10.8	18.8	14.9	14	91	NS	NS
Romano-British	14.5	0.46	1.2	13.2	16.3	8.3	7	14.2	0.84	2.4	10.8	18.6	16.7	8	98	NS	NS
Aust.Aborigines	19.8	0.98	2.2	17.8	23.1	11.1	5	16.4	0.59	1.4	15.0	18.8	8.8	6	83	<.05	NS
3RP^4 1																	
Gorilla	18.7	0.39	1.9	15.5	23.3	10.1	23	17.2	0.58	2.4	13.3	22.8	13.8	17	92	<.05	NS
Pan	13.9	-	-	13.4	14.8	-	3	11.5	-	-	10.1	12.8	-	2	83	-	-
Pongo	19.1	0.56	2.3	14.9	21.8	11.8	16	18.3	0.97	3.2	14.0	25.9	17.7	11	96	NS	NS
3RP^4 mb																	
Gorilla	19.6	0.71	3.4	15.0	27.1	17.5	23	17.6	0.95	3.9	12.9	25.8	22.3	17	90	NS	NS
Pan	13.6	-	-	12.0	15.2	-	3	10.6	-	-	10.0	11.1	-	2	78	-	-
Pongo	20.2	0.74	3.0	15.0	23.9	14.6	16	17.8	1.13	3.7	13.9	26.9	21.0	11	88	NS	NS
3RP^4 db																	
Gorilla	18.0	0.57	2.7	13.8	24.0	15.2	23	16.5	0.79	3.3	13.3	25.7	19.8	17	92	NS	NS
Pan	12.9	-	-	11.2	14.3	-	3	10.8	-	-	10.1	11.4	-	2	84	-	-
Pongo	18.2	0.58	2.3	13.6	22.2	12.8	16	16.7	1.08	3.6	13.4	26.6	21.4	11	92	NS	NS
2RP^4 1																	
Pan	13.7	0.39	1.6	10.5	15.7	11.8	17	12.2	0.55	1.6	9.8	14.2	12.7	8	89	<.05	NS
Pongo	18.3	-	-	-	-	-	1	16.0	-	-	-	-	-	1	-	-	-
2RP^4 b																	
Pan	14.9	0.60	2.5	10.2	18.8	16.7	17	13.5	0.72	2.0	10.4	15.9	15.2	8	91	NS	NS
Pongo	19.0	-	-	-	-	-	1	18.2	-	-	-	-	-	1	-	-	-

Table 7.7: Actual root height

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t	F
$1RP^4$																	
H.sapiens(pooled)	16.7	0.70	2.8	13.5	23.7	16.8	16	15.3	0.50	2.0	11.8	18.6	13.1	16	92	NS	NS
Romano-British	15.4	0.53	1.7	13.5	18.8	10.8	10	14.3	0.63	1.9	11.8	17.7	13.3	9	93	NS	NS
Aust.Aborigines	19.0	1.22	3.0	15.9	23.7	15.8	6	16.6	0.49	1.3	15.1	18.6	7.8	7	87	NS	NS
M^1 l																	
Gorilla	18.9	0.40	1.9	14.5	22.2	10.1	23	17.7	0.40	1.6	14.6	20.8	9.2	17	94	NS	NS
Pan	13.6	0.38	1.7	10.0	16.2	12.4	20	12.0	0.34	1.1	10.2	13.4	9.3	11	88	<.05	NS
Pongo	17.1	0.50	2.1	13.3	20.1	12.5	18	15.6	0.31	1.2	13.1	17.8	7.5	14	91	<.05	<.05
H.sapiens(pooled)	13.4	0.42	1.6	11.4	16.3	12.0	15	13.3	0.36	1.4	10.9	16.4	10.7	16	99	NS	NS
Romano-British	12.9	0.31	1.0	11.4	14.5	7.7	10	12.9	0.29	0.8	11.7	14.0	6.4	8	100	NS	NS
Aust.Aborigines	14.4	0.98	2.2	11.4	16.3	15.2	5	13.7	0.64	1.8	10.9	16.4	13.1	8	95	NS	NS
M^1 mb																	
Gorilla	15.9	0.46	2.2	11.4	22.0	13.8	23	15.7	0.76	3.2	12.0	23.6	20.1	17	99	NS	NS
Pan	11.4	0.47	2.1	7.8	15.2	18.4	20	10.8	0.45	1.5	8.0	13.6	13.9	11	95	NS	NS
Pongo	17.0	0.62	2.6	12.5	21.4	15.4	18	16.0	0.73	2.7	12.8	22.6	17.1	14	94	NS	NS
H.sapiens(pooled)	13.4	0.33	1.3	11.2	15.5	9.5	15	12.1	0.35	1.4	10.0	15.1	11.7	16	90	<.05	NS
Romano-British	12.9	0.38	1.2	11.2	15.5	9.3	10	11.5	0.50	1.4	10.0	13.7	12.3	8	89	<.05	NS
Aust.Aborigines	14.3	0.37	0.8	13.3	15.1	5.7	5	12.6	0.44	1.3	11.1	15.1	9.9	8	88	<.05	NS

G(iii): Actual root height

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t F
M_1^1 db																
Gorilla	16.8	0.62	3.0	11.0	23.1	17.7	23	16.9	0.47	2.0	13.4	20.7	11.6	17	101	NS NS
Pan	11.8	0.47	2.1	8.5	15.7	17.8	20	11.4	0.60	2.0	8.2	15.3	17.4	11	97	NS NS
Pongo	16.6	0.51	2.2	12.4	19.4	13.0	18	15.2	0.64	2.4	12.6	19.5	15.8	14	92	NS NS
H.sapiens(pooled)	12.9	0.33	1.3	10.7	15.2	10.0	15	11.6	0.39	1.6	8.9	14.4	13.4	16	90	<.05 NS
Romano-British	12.5	0.36	1.1	10.7	14.6	9.0	10	11.1	0.64	1.8	8.9	13.9	16.2	8	89	NS NS
Aust.Aborigines	13.8	0.54	1.2	12.0	15.2	8.8	5	12.0	0.42	1.2	10.5	14.4	9.9	8	87	<.05 NS
M_1^2 1																
Gorilla	18.0	0.39	1.8	15.1	21.7	10.0	21	16.7	0.42	1.6	13.5	19.2	9.8	15	93	<.05 NS
Pan	12.7	0.31	1.4	9.7	14.4	10.9	20	11.3	0.43	1.4	8.9	13.5	12.0	10	89	<.05 NS
Pongo	16.8	0.66	2.5	13.1	21.8	14.7	14	15.5	0.71	2.7	9.5	22.0	17.7	15	93	NS NS
H.sapiens(pooled)	14.1	0.47	1.8	11.7	17.6	12.8	15	12.4	0.21	0.8	11.3	13.4	6.1	13	88	<.01 <.01
Romano-British	13.1	0.46	1.4	11.7	15.5	10.5	9	12.4	0.42	0.9	11.3	13.4	7.5	5	95	NS NS
Aust.Aborigines	15.6	0.46	1.1	14.2	17.6	7.2	6	12.4	0.24	0.7	11.5	13.1	5.5	8	80	<.001 NS
M_2^2 mb																
Gorilla	17.3	0.68	3.1	11.8	23.5	18.0	21	16.1	0.56	2.2	13.2	20.0	13.4	15	93	NS NS
Pan	12.0	0.40	1.8	8.0	15.5	14.8	20	10.5	0.64	2.0	8.4	14.6	19.1	10	88	NS NS
Pongo	16.7	0.77	2.0	11.8	20.9	17.3	14	15.4	0.62	2.4	11.0	19.3	15.6	15	92	NS NS
H.sapiens(pooled)	13.4	0.42	1.6	11.4	17.2	12.2	15	13.0	0.30	1.1	11.0	14.2	8.4	13	97	NS NS
Romano-British	12.5	0.33	1.0	11.4	14.1	8.0	9	11.9	0.44	1.0	11.0	13.2	8.3	5	95	NS NS
Aust.Aborigines	14.8	0.56	1.4	13.1	17.2	9.2	6	13.6	0.17	0.5	12.9	14.2	3.5	8	92	NS <.05

G(111): Actual root height

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t F
$M_{\underline{}}^{2}$ db																
Gorilla	17.4	0.72	3.3	13.2	26.2	19.0	21	16.1	0.60	2.3	12.9	19.9	14.4	15	93	NS NS
Pan	11.5	0.46	2.1	6.8	14.9	17.9	20	10.7	0.58	1.8	7.9	14.5	17.0	10	93	NS NS
Pongo	16.9	0.80	3.0	11.9	21.6	17.8	14	15.2	0.57	2.2	11.2	18.7	14.5	15	90	NS NS
H.sapiens(pooled)	13.1	0.49	1.9	11.3	17.4	14.4	15	12.3	0.27	1.0	10.0	13.6	8.1	13	94	NS <.05
Romano-British	12.2	0.23	0.7	11.3	13.0	5.7	9	11.4	0.43	1.0	10.0	12.6	8.5	5	93	NS NS
Aust.Aborigines	14.6	0.91	2.2	11.8	17.4	15.3	6	12.8	0.19	0.5	12.1	13.6	4.3	8	88	NS <.01
$M_{\underline{}}^{3}$ 1																
Gorilla	16.9	0.44	2.1	13.7	20.9	12.4	23	14.8	0.33	1.2	12.8	16.8	8.4	14	88	<.01 NS
Pan	11.6	0.26	1.2	8.5	13.4	10.2	20	10.7	0.34	1.1	9.8	13.3	10.0	10	92	NS NS
Pongo	16.4	0.54	1.9	11.7	18.5	11.7	13	13.4	0.46	1.5	11.2	15.9	11.4	11	82	<.001 NS
H.sapiens(pooled)	13.7	0.95	2.3	10.4	16.3	17.0	6	11.9	0.35	0.9	11.0	13.5	7.3	6	87	NS <.05
Romano-British	10.9	-	-	10.4	11.4	-	2	11.7	-	-	11.4	11.9	-	2	107	- -
Aust.Aborigines	15.1	-	-	14.0	16.3	-	4	12.0	-	-	11.0	13.5	-	4	80	- -
$M_{\underline{}}^{3}$ mb																
Gorilla	16.5	0.66	3.2	12.6	26.8	19.3	23	14.9	0.64	2.4	11.8	19.8	16.1	14	90	NS NS
Pan	10.9	0.39	1.7	8.0	13.6	15.9	20	10.3	0.36	1.1	8.5	12.2	11.0	10	95	NS NS
Pongo	15.8	0.48	1.7	12.0	18.8	11.0	13	12.5	0.50	1.7	10.4	15.6	13.3	11	79	<.001 NS
H.sapiens(pooled)	14.3	1.22	3.0	11.3	19.2	21.0	6	12.4	1.02	2.5	10.2	16.7	20.1	6	87	NS NS
Romano-British	11.6	-	-	11.3	11.9	-	2	13.5	-	-	10.2	16.7	-	2	116	- -
Aust.Aborigines	15.6	-	-	12.7	19.2	-	4	11.9	-	-	10.5	14.0	-	4	76	- -

G(iii): Actual root height

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t F
$M_{\underline{3}}^{3}$ db																
Gorilla	15.8	0.64	3.1	10.8	21.5	19.4	23	14.1	0.62	2.3	10.9	19.1	16.4	14	89	NS NS
Pan	10.5	0.40	1.8	6.5	13.4	16.9	20	10.1	0.36	1.2	8.6	11.7	11.3	10	96	NS NS
Pongo	15.4	0.66	2.4	11.8	20.3	15.4	13	12.7	0.55	1.8	10.6	16.3	14.4	11	83	<.01 NS
H.sapiens(pooled)	13.8	1.01	2.5	11.4	18.0	18.0	6	11.9	0.86	2.1	9.6	14.8	17.7	6	86	NS NS
Romano-British	11.4	-	-	11.4	11.4	-	2	12.2	-	-	9.6	14.8	-	2	107	- -
Aust.Aborigines	15.0	-	-	13.3	18.0	-	4	11.8	-	-	10.6	14.2	-	4	79	- -

	Males							Females							%SD	P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N		t	F
I_1																	
Gorilla	22.0	0.75	2.9	17.7	28.8	13.2	15	19.4	0.39	1.4	17.3	22.7	7.2	13	88	<.01	<.05
Pan	16.7	0.45	1.9	12.6	19.0	11.2	17	16.2	0.46	1.4	13.7	18.4	8.6	9	97	NS	NS
Pongo	22.3	0.60	2.4	18.7	27.4	10.7	16	19.8	0.48	1.9	17.1	23.4	9.4	15	89	<.01	NS
H.sapiens(pooled)	13.5	0.69	2.3	10.9	17.1	16.9	11	12.5	0.30	1.1	10.2	14.3	9.0	14	93	NS	<.05
Romano-British	12.6	0.63	1.8	10.9	15.3	11.5	17	12.2	0.36	1.1	10.2	14.3	8.9	9	97	NS	NS
Aust.Aborigines	15.9	-	-	14.1	17.1	-	3	13.1	0.47	1.0	11.7	14.2	8.0	5	82	-	-
I_2																	
Gorilla	23.3	0.49	2.2	18.9	27.8	9.4	20	20.3	0.32	1.3	17.2	22.9	6.2	16	87	<.001	<.05
Pan	17.1	0.60	2.5	11.6	22.0	14.5	17	16.6	0.63	1.9	13.4	19.4	11.4	9	97	NS	NS
Pongo	22.8	0.55	2.3	19.7	28.8	10.0	17	20.6	0.55	2.1	17.6	24.3	9.9	14	90	.01	NS
H.sapiens(pooled)	14.9	0.43	1.6	12.8	18.7	10.7	14	13.7	0.45	1.8	10.5	18.8	13.2	16	92	NS	NS
Romano-British	14.3	0.32	1.0	12.8	15.7	7.0	10	14.1	0.58	1.8	12.3	18.8	12.9	10	99	NS	NS
Aust.Aborigines	16.7	-	-	14.8	18.7	-	4	13.0	0.71	1.7	10.5	15.9	13.3	6	78	-	-
$2RP_3$ m																	
Gorilla	23.4	0.57	2.7	19.6	28.5	11.7	23	20.8	0.57	2.3	18.0	26.1	10.9	16	89	<.01	NS
Pan	18.0	0.65	2.6	12.2	21.8	14.3	16	17.6	0.94	2.3	13.5	19.8	13.1	6	98	NS	NS
Pongo	26.3	0.64	2.6	22.8	32.1	10.0	17	23.1	1.04	3.8	19.0	32.5	16.3	13	88	.01	NS
Aust.Aborigines	16.1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t F
$2RP_3$ d																
Gorilla	23.2	0.63	3.0	18.6	31.6	13.1	23	20.1	0.58	2.3	17.2	26.1	11.6	16	87	<.01 NS
Pan	17.5	0.61	2.5	12.2	20.8	14.0	16	17.2	0.72	1.8	13.8	18.6	10.3	6	98	NS NS
Pongo	24.8	0.70	2.9	20.3	30.2	11.6	17	20.9	1.10	4.0	16.3	32.8	19.0	13	84	<.01 NS
Aust.Aborigines	15.8	-	-	-	-	-	1	-	-	-	-	-	-	-	-	- -
$1RP_3$																
Pan	17.5	-	-	15.5	18.9	-	4	16.7	0.68	1.5	15.7	19.4	9.1	5	95	- -
Pongo	-	-	-	-	-	-	-	24.8	-	-	-	-	-	1	-	- -
H.sapiens(pooled)	16.1	0.54	2.0	13.5	20.1	12.7	14	15.1	0.39	1.6	12.6	18.4	10.5	17	94	NS NS
Romano-British	15.0	0.33	1.1	13.5	16.6	7.0	10	14.9	0.57	1.8	12.6	18.4	12.1	10	99	NS NS
Aust.Aborigines	18.7	-	-	17.1	20.1	-	4	15.4	1.31	1.3	13.0	16.6	8.5	7	82	- -
$2RP_4$ m																
Gorilla	21.0	0.39	1.8	17.6	24.1	8.8	22	19.6	0.48	1.9	15.3	23.1	9.5	15	93	<.05 NS
Pan	17.7	0.50	2.2	13.3	23.3	12.7	20	15.8	0.54	1.8	12.3	18.6	11.4	11	89	<.05 NS
Pongo	23.9	0.71	2.9	19.5	29.6	12.2	17	21.2	1.02	4.0	14.8	31.3	18.7	15	89	<.05 NS
$2RP_4$ d																
Gorilla	21.3	0.41	1.9	17.8	24.8	8.9	22	19.7	0.32	1.3	17.3	22.1	6.6	16	93	<.01 NS
Pan	17.0	0.38	1.7	12.6	20.1	10.1	20	15.5	0.44	1.4	12.9	17.7	9.3	11	91	<.05 NS
Pongo	22.6	0.57	2.3	18.4	26.7	10.3	17	20.4	1.01	3.9	14.8	31.8	19.3	15	90	NS <.05

G(IV): Projected root height

	Males						Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t	F
$_{1}RP_{4}$																	
H.sapiens(pooled)	16.7	0.55	2.1	13.3	21.2	12.7	15	15.1	0.40	1.7	12.4	18.5	11.4	18	90	<.05	NS
Romano-British	16.0	0.59	1.9	13.3	19.2	11.6	10	14.6	0.65	2.0	12.4	18.5	13.9	10	91	NS	NS
Aust.Aborigines	18.2	0.90	2.0	15.7	21.2	11.1	5	15.6	0.39	1.1	13.6	17.0	7.0	8	86	<.05	NS
M_{1}- m																	
Gorilla	18.4	0.55	2.7	15.0	23.9	14.5	23	17.4	0.43	1.8	13.0	19.6	10.2	17	95	NS	NS
Pan	13.3	0.31	1.4	11.1	15.9	10.2	20	12.8	0.50	1.7	10.7	14.8	12.9	11	96	NS	NS
Pongo	21.3	0.59	2.6	16.5	25.3	12.1	19	18.9	0.60	2.3	14.4	24.0	12.2	15	89	.01	NS
H.sapiens(pooled)	14.9	0.41	1.7	12.8	18.5	11.0	16	13.6	0.32	1.3	11.3	15.5	9.7	17	91	<.05	NS
Romano-British	14.3	0.50	1.6	12.8	18.5	11.0	10	13.3	0.50	1.6	11.3	15.5	11.8	10	93	NS	NS
Aust.Aborigines	15.9	0.54	1.3	14.8	18.3	8.3	6	14.0	0.30	0.8	12.6	15.0	5.7	7	88	<.01	NS
M_{1}- d																	
Gorilla	18.8	0.60	2.9	14.3	27.1	15.4	23	18.2	0.35	1.4	15.6	19.7	7.8	17	97	NS	<.01
Pan	14.1	0.25	1.1	12.1	15.9	8.1	20	13.5	0.41	1.4	11.6	15.8	10.1	11	96	NS	NS
Pongo	20.7	0.62	2.7	16.7	26.0	13.1	19	18.3	0.61	2.4	13.1	24.0	12.9	15	88	<.05	NS
H.sapiens(pooled)	13.9	0.39	1.6	11.3	17.5	11.3	16	12.9	0.23	1.0	10.6	14.1	7.4	17	93	<.05	NS
Romano-British	13.3	0.42	1.3	11.3	16.1	10.0	10	12.6	0.35	1.1	10.6	14.1	8.7	10	95	NS	NS
Aust.Aborigines	14.8	0.66	1.6	13.0	17.5	10.9	6	13.4	0.18	0.5	12.6	14.0	3.6	7	91	NS	<.05

d(IV): Projected foot height

	Males						Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t	F
M_2 m																	
Gorilla	20.2	0.52	2.5	16.3	26.6	12.3	23	18.0	0.31	1.3	15.3	20.2	7.1	17	89	.001	<.01
Pan	13.0	0.33	1.5	9.8	15.5	11.2	20	12.9	0.42	1.4	10.8	14.8	10.8	11	99	NS	NS
Pongo	21.4	0.60	2.5	17.1	25.6	11.5	17	19.0	0.79	3.0	15.0	26.3	15.6	14	89	<.05	NS
H.sapiens(pooled)	14.4	0.45	1.8	12.1	17.5	12.5	16	13.0	0.33	1.4	10.6	15.3	10.6	17	90	<.05	NS
Romano-British	13.4	0.36	1.2	12.1	15.4	8.6	10	12.5	0.53	1.6	10.6	15.3	12.7	9	93	NS	NS
Aust.Aborigines	16.1	0.56	1.4	13.8	17.5	8.5	6	13.7	0.27	0.8	12.3	15.1	5.7	8	85	.001	NS
M_2 d																	
Gorilla	18.7	0.61	2.9	14.4	25.4	15.6	23	17.0	0.26	1.0	14.8	18.8	6.1	16	91	<.05	<.001
Pan	12.8	0.40	1.8	9.2	16.6	14.0	20	12.3	0.41	1.4	10.0	14.6	11.0	11	96	NS	NS
Pongo	20.8	0.64	2.5	16.6	24.1	12.0	15	17.8	0.98	3.5	14.0	27.4	19.9	13	86	<.05	NS
H.sapiens(pooled)	13.9	0.48	1.9	10.6	16.8	13.8	16	12.5	0.33	1.4	9.7	14.8	10.9	17	90	<.05	NS
Romano-British	12.9	0.41	1.3	10.6	15.3	10.2	10	11.8	0.50	1.5	9.7	14.8	12.8	9	92	NS	NS
Aust.Aborigines	15.6	0.62	1.5	13.2	16.8	9.7	6	13.2	0.26	0.7	12.4	14.4	5.5	8	85	<.01	NS
M_3 m																	
Gorilla	17.5	0.54	2.5	12.7	24.4	14.5	22	15.2	0.32	1.2	12.9	17.3	8.1	15	87	.001	<.01
Pan	10.7	0.29	1.3	8.8	13.3	12.0	20	10.1	0.42	1.4	8.3	12.6	13.9	11	94	NS	NS
Pongo	18.7	0.72	2.6	13.6	22.1	13.9	13	15.4	0.66	1.7	13.0	17.5	11.2	7	82	<.01	NS
H.sapiens(pooled)	12.3	0.54	2.0	10.5	16.7	15.8	13	12.5	0.48	1.8	10.2	15.4	14.3	14	102	NS	NS
Romano-British	11.3	0.30	0.9	10.5	12.9	7.6	8	12.3	0.78	2.1	10.2	14.9	16.7	7	109	NS	<.05
Aust.Aborigines	14.0	0.94	2.1	11.5	16.7	15.1	5	12.6	0.61	1.6	11.2	15.4	12.8	7	90	NS	NS

G(iv): Projected root height

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t F
M_3 d																
Gorilla	14.0	0.61	2.7	10.1	18.8	18.9	19	12.5	0.31	1.1	9.9	14.0	8.9	13	89	<.05 <.01
Pan	9.8	0.33	1.5	7.5	13.7	14.8	19	9.5	0.45	1.4	7.7	12.0	14.9	10	97	NS NS
Pongo	16.9	0.87	3.0	11.6	21.6	17.9	12	13.4	0.48	1.3	11.0	14.9	9.4	7	79	<.05 <.05
H.sapiens(pooled)	11.4	0.47	1.7	9.2	14.7	15.0	13	11.7	0.38	1.4	9.5	14.2	12.1	14	103	NS NS
Romano-British	10.5	0.32	0.9	9.2	11.7	8.6	8	11.2	0.58	1.5	9.5	13.5	13.6	7	107	NS NS
Aust.Aborigines	12.9	0.78	1.7	11.0	14.7	13.5	5	12.1	0.47	1.3	10.7	14.2	10.4	7	94	NS NS
I_1																
Gorilla	23.8	0.79	3.3	19.2	31.3	14.0	18	20.7	0.45	1.6	17.2	22.6	7.8	13	87	<.01 <.05
Pan	19.1	0.61	2.5	13.4	23.7	13.1	17	19.4	0.40	1.3	17.6	21.3	6.8	11	102	NS <.05
Pongo	21.5	0.45	1.9	18.3	24.3	8.6	17	20.1	0.84	2.9	15.7	28.3	14.5	12	94	NS NS
H.sapiens(pooled)	13.1	0.43	1.5	11.1	16.1	11.3	12	12.5	0.44	1.6	9.8	16.0	12.7	13	95	NS NS
Romano-British	12.6	0.35	1.1	11.1	14.4	8.9	10	12.1	0.45	1.3	9.8	14.3	11.0	9	96	NS NS
Aust.Aborigines	15.3	-	-	14.4	16.1	-	2	13.4	-	-	11.5	16.0	-	4	88	- -
I_2																
Gorilla	23.6	0.65	2.4	19.3	28.2	10.4	14	20.2	0.61	2.0	16.5	23.8	10.0	11	86	.001 NS
Pan	17.7	0.65	2.4	13.9	22.3	13.7	14	17.3	0.58	1.8	15.0	20.6	10.6	10	98	NS NS
Pongo	21.1	0.61	2.6	16.5	24.5	12.2	18	19.8	0.82	2.8	15.3	27.4	14.4	12	94	NS NS
H.sapiens(pooled)	13.8	0.73	2.7	11.2	21.1	19.6	14	12.7	0.40	1.6	10.6	15.5	12.3	15	92	NS <.05
Romano-British	12.3	0.25	0.8	11.2	13.5	6.1	9	12.0	0.35	1.0	10.6	13.5	8.3	8	98	NS NS
Aust.Aborigines	16.6	1.24	2.8	14.0	21.1	16.7	5	13.5	0.66	1.8	11.1	15.5	12.9	7	81	<.05 NS

G(iv): Projected root height

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t F
3RP^3_ 1																
Gorilla	20.0	0.61	2.9	14.1	27.8	14.3	22	18.0	0.64	2.6	12.5	24.1	14.6	17	90	<.05 NS
Pan	14.0	0.38	1.6	10.9	16.6	11.5	18	13.2	0.43	1.3	10.7	14.6	9.8	9	94	NS NS
Pongo	19.9	0.67	2.5	16.3	23.5	12.5	14	18.6	0.46	1.5	15.8	20.5	7.9	10	94	NS NS
3RP^3_ mb																
Gorilla	24.1	0.90	4.2	16.5	33.0	17.5	22	20.6	0.83	3.4	15.7	27.3	16.7	17	86	<.01 NS
Pan	14.7	0.55	2.3	12.0	18.8	15.9	18	13.6	0.91	2.7	8.9	17.7	20.1	9	93	NS NS
Pongo	21.7	0.62	2.3	17.6	24.8	10.7	14	20.4	1.06	3.4	15.8	26.4	16.4	10	94	NS NS
3RP^3_ db																
Gorilla	19.0	0.78	3.6	13.7	25.8	19.2	22	16.7	0.85	3.5	12.3	25.6	21.0	17	88	NS NS
Pan	12.1	0.46	2.0	8.1	16.5	16.3	18	11.6	0.58	1.8	8.3	14.5	15.1	9	96	NS NS
Pongo	18.3	0.52	1.9	14.9	20.9	10.6	14	17.2	1.09	3.4	13.3	22.4	19.9	10	94	NS NS
2RP^3_ 1																
Pan	13.5	-	-	-	-	-	1	12.7	-	-	12.4	13.0	-	2	-	- -
Pongo	-	-	-	-	-	-	-	18.5	-	-	16.5	20.4	-	2	-	- -
H.sapiens(pooled)	12.7	-	-	10.9	13.4	-	4	14.9	-	-	-	-	-	1	-	- -
Romano-British	12.5	-	-	10.9	13.4	-	3	-	-	-	-	-	-	-	-	- -
Aust.Aborigines	13.2	-	-	-	-	-	1	14.9	-	-	-	-	-	1	-	- -

G(iv): Projected root height

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t	F
2RP^{3} b																	
Pan	15.0	-	-	-	-	-	1	14.1	-	-	13.0	15.1	-	2	-	-	-
Pongo	-	-	-	-	-	-	-	21.5	-	-	19.7	23.2	-	2	-	-	-
H.sapiens(pooled)	13.4	-	-	12.2	15.1	-	4	16.3	-	-	-	-	-	1	-	-	-
Romano-British	12.9	-	-	12.2	13.4	-	3	-	-	-	-	-	-	-	-	-	-
Aust.Aborigines	15.1	-	-	-	-	-	1	16.3	-	-	-	-	-	1	-	-	-
1RP^{3}																	
H.sapiens(pooled)	16.7	0.92	3.2	13.2	21.1	19.1	12	15.2	0.59	2.2	10.8	18.8	14.5	14	91	NS	NS
Romano-British	14.4	0.46	1.2	13.2	16.3	8.4	7	14.3	0.82	2.3	10.8	18.6	16.2	8	99	NS	NS
Aust.Aborigines	19.8	0.99	2.2	17.8	23.1	11.2	5	16.4	0.59	1.5	15.0	18.8	8.9	6	83	<.05	NS
3RP^{4} l																	
Gorilla	18.6	0.38	1.8	15.5	23.3	9.9	23	17.1	0.57	2.4	13.3	22.8	13.8	17	92	<.05	NS
Pan	13.9	-	-	13.3	14.8	-	3	11.5	-	-	10.1	12.8	-	2	83	-	-
Pongo	19.0	0.56	2.2	14.6	21.8	11.8	16	18.0	0.94	3.1	13.7	25.2	17.2	11	95	NS	NS
3RP^{4} mb																	
Gorilla	19.4	0.70	3.3	15.0	26.5	17.2	23	17.6	0.94	3.9	12.8	25.4	22.1	17	91	NS	NS
Pan	13.6	-	-	12.0	15.2	-	3	10.6	-	-	10.0	11.1	-	2	78	-	-
Pongo	20.2	0.73	2.9	15.0	23.7	14.5	16	17.7	1.13	3.7	13.7	26.6	21.2	11	88	NS	NS
3RP^{4} db																	
Gorilla	17.6	0.54	2.6	13.6	23.4	14.6	23	16.3	0.78	3.2	12.7	25.2	19.8	17	93	NS	NS
Pan	12.9	-	-	11.2	14.3	-	3	10.8	-	-	10.1	11.4	-	2	84	-	-
Pongo	18.1	0.56	2.2	13.6	21.6	12.3	16	16.4	1.10	3.7	13.2	26.4	22.2	11	91	NS	NS

G (iv): Projected root height

	Males							Females							%SD	P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N		t	F
$2RP^{4}$ 1																	
Pan	13.6	0.39	1.6	10.5	15.6	11.9	17	12.2	0.56	1.6	9.7	14.2	13.0	8	90	<.05	NS
Pongo	18.2	-	-	-	-	-	2	15.6	-	-	-	-	-	1	-	-	-
$2RP^{4}$ b																	
Pan	14.8	0.60	2.5	10.2	18.8	16.7	17	13.5	0.72	2.1	10.4	15.9	15.2	8	91	NS	NS
Pongo	18.0	-	-	-	-	-	1	17.8	-	-	-	-	-	1	-	-	-
$1RP^{4}$																	
H.sapiens(pooled)	16.7	0.70	2.8	13.5	23.7	16.7	16	15.3	0.50	2.0	11.8	18.6	13.2	16	92	NS	NS
Romano-British	15.4	0.53	1.7	13.5	18.8	10.8	10	14.2	0.63	1.9	11.8	17.7	13.3	9	92	NS	NS
Aust.Aborigines	18.9	1.24	3.0	15.8	23.7	16.0	6	16.6	0.49	1.3	15.1	18.6	7.8	7	88	NS	NS
M^{1} 1																	
Gorilla	18.7	0.39	1.9	14.5	21.4	9.9	23	17.5	0.38	1.6	14.4	20.3	9.0	17	94	<.05	NS
Pan	13.4	0.37	1.6	10.0	16.2	12.2	20	11.9	0.34	1.1	10.2	13.1	9.5	11	89	.01	NS
Pongo	16.9	0.51	2.2	13.2	20.0	12.7	18	15.3	0.29	1.1	12.9	17.2	7.2	14	91	<.05	<.05
H.sapiens(pooled)	13.3	0.43	1.7	11.2	16.3	12.5	15	13.2	0.38	1.5	10.5	16.4	11.5	16	99	NS	NS
Romano-British	12.8	0.34	1.1	11.2	14.5	8.4	10	12.7	0.32	0.9	11.7	14.0	7.1	8	99	NS	NS
Aust.Aborigines	14.4	0.99	2.2	11.4	16.3	15.4	5	13.6	0.68	1.9	10.5	16.4	14.1	8	94	NS	NS

G(iv): Projected root height

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t F
$M_{\overline{1}}^{1}$ mb																
Gorilla	15.5	0.43	2.1	11.2	21.4	13.2	23	15.6	0.75	3.1	11.9	23.2	19.9	17	101	NS NS
Pan	11.3	0.46	2.0	7.8	15.0	18.0	20	10.7	0.45	1.5	8.0	13.6	13.9	11	95	NS NS
Pongo	16.6	0.62	2.6	12.2	21.3	15.8	18	15.4	0.60	2.2	12.7	19.9	14.4	14	93	NS NS
H.sapiens(pooled)	13.3	0.32	1.3	11.2	15.5	9.4	15	12.0	0.36	1.4	9.6	14.9	11.9	16	90	.01 NS
Romano-British	12.8	0.38	1.2	11.2	15.5	9.3	10	11.4	0.52	1.5	9.6	13.6	12.8	8	89	<.05 NS
Aust.Aborigines	14.2	0.37	0.8	13.2	15.1	5.8	5	12.5	0.43	1.2	10.9	14.9	9.8	8	88	<.05 NS
$M_{\overline{1}}^{1}$ db																
Gorilla	16.1	0.55	2.6	10.7	21.4	16.3	23	16.4	0.50	2.1	13.0	20.7	12.5	17	102	NS NS
Pan	11.5	0.48	2.1	8.4	15.5	18.5	20	11.2	0.59	2.0	8.2	15.3	17.4	11	97	NS NS
Pongo	16.2	0.49	2.1	12.3	18.9	12.9	18	14.7	0.65	2.5	11.5	18.9	16.7	14	91	NS NS
H.sapiens(pooled)	12.7	0.37	1.4	9.9	15.0	11.1	15	11.3	0.39	1.6	8.6	14.1	13.8	16	89	<.05 NS
Romano-British	12.3	0.42	1.3	9.9	14.6	10.7	10	10.9	0.64	1.8	8.6	13.6	16.5	8	89	NS NS
Aust.Aborigines	13.6	0.57	1.3	11.7	15.0	9.3	5	11.8	0.43	1.2	10.2	14.1	10.4	8	87	<.05 NS
$M_{\overline{2}}^{2}$ l																
Gorilla	17.9	0.40	1.8	15.0	21.7	10.1	21	16.5	0.44	1.7	13.0	18.8	10.3	15	92	.05 NS
Pan	12.6	0.31	1.4	9.4	14.3	11.1	20	11.1	0.39	1.2	8.9	12.9	11.0	10	88	.01 NS
Pongo	16.4	0.64	2.4	13.0	21.6	14.6	14	15.1	0.71	2.7	9.5	21.7	18.1	15	92	NS NS
H.sapiens(pooled)	13.9	0.47	1.8	11.5	17.5	13.2	15	12.1	0.21	0.7	10.8	13.2	6.2	13	87	.01 .01
Romano-British	12.9	0.48	1.4	11.5	15.5	11.2	9	12.1	0.48	1.1	10.8	13.2	8.9	5	94	NS NS
Aust.Aborigines	15.4	0.46	1.1	14.2	17.5	7.3	6	12.0	0.18	0.5	11.2	12.8	4.4	8	78	.001 NS

GRIV7. Projected root height

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t F
M^2 mb																
Gorilla	17.2	0.66	3.0	11.8	22.9	17.7	21	15.9	0.56	2.2	13.1	19.7	13.5	15	92	NS NS
Pan	11.9	0.39	1.7	8.0	15.5	14.5	20	10.5	0.64	2.0	8.4	14.6	19.1	10	88	NS NS
Pongo	16.5	0.75	2.8	11.8	20.9	17.1	14	15.2	0.59	2.3	11.0	19.1	15.1	15	92	NS NS
H.sapiens(pooled)	13.2	0.44	1.7	11.3	17.2	13.0	15	12.7	0.27	1.0	10.9	14.0	7.7	13	96	NS NS
Romano-British	12.2	0.33	1.0	11.3	13.9	8.2	9	11.8	0.40	0.9	10.9	12.9	7.7	5	97	NS NS
Aust.Aborigines	14.7	0.62	1.5	12.6	17.2	10.4	6	13.3	0.15	0.4	12.7	14.0	3.1	8	91	NS <.01
M^2 db																
Gorilla	17.3	0.71	3.3	13.2	26.2	18.8	21	16.0	0.60	2.3	12.7	19.8	14.6	15	93	NS NS
Pan	11.3	0.46	2.1	6.5	14.6	18.4	20	10.6	0.58	1.8	7.9	14.5	17.3	10	94	NS NS
Pongo	16.7	0.79	3.0	11.6	21.3	17.6	14	15.0	0.57	2.2	11.2	18.5	14.6	15	90	NS NS
H.sapiens(Pooled)	13.0	0.49	1.9	11.2	17.1	14.8	15	12.0	0.31	1.1	9.2	13.4	9.3	13	92	NS NS
Romano-British	12.0	0.22	0.7	11.2	12.9	5.5	9	11.0	0.51	1.1	9.2	12.1	10.3	5	92	NS NS
Aust.Aborigines	14.4	0.95	2.3	11.5	17.1	16.1	6	12.6	0.21	0.6	11.8	13.4	4.6	8	88	NS <.01
M^3 l																
Gorilla	16.4	0.40	1.9	13.7	20.8	11.9	23	14.1	0.32	1.2	12.5	16.1	8.4	14	86	<.001 NS
Pan	11.3	0.26	1.2	8.3	13.2	10.3	20	10.3	0.32	1.0	9.4	12.6	9.7	10	91	<.05 NS
Pongo	15.5	0.54	2.0	11.1	17.9	12.7	13	12.7	0.44	1.5	10.7	15.6	11.4	11	82	.001 NS
H.sapiens(pooled)	13.3	0.83	2.0	10.4	15.2	15.3	6	11.6	0.34	0.8	10.9	13.1	7.1	6	87	NS NS
Romano-British	10.8	-	-	10.4	11.1	-	2	11.4	-	-	10.9	11.8	-	2	106	- -
Aust.Aborigines	14.6	-	-	13.8	15.2	-	4	11.7	-	-	11.0	13.1	-	4	80	- -

G(iv): Projected root height

	Males							Females							%SD	P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N		t	F
M^3 mb																	
Gorilla	16.3	0.67	3.2	12.6	26.5	19.7	23	14.6	0.59	2.2	11.4	18.9	15.1	14	90	NS	NS
Pan	10.8	0.39	1.8	7.8	13.5	16.3	20	10.3	0.34	1.1	8.4	11.9	10.5	10	95	NS	NS
Pongo	15.6	0.48	1.8	11.9	18.6	11.2	13	12.5	0.51	1.7	10.2	15.6	13.7	11	80	<.001	NS
H.sapiens(pooled)	13.8	1.03	2.5	11.3	17.9	18.3	6	12.0	0.94	2.3	9.2	15.5	19.2	6	87	NS	NS
Romano-British	11.5	-	-	11.3	11.7	-	2	12.4	-	-	9.2	15.5	-	2	108	-	-
Aust.Aborigines	14.9	-	-	12.5	17.9	-	4	11.8	-	-	10.5	13.8	-	4	79	-	-
M^3 db																	
Gorilla	15.5	0.63	3.0	9.5	20.8	19.5	23	13.7	0.60	2.2	10.7	18.1	16.3	14	88	NS	NS
Pan	10.2	0.43	1.9	5.9	13.4	18.6	20	9.9	0.34	1.1	8.2	11.4	10.9	10	97	NS	NS
Pongo	14.4	0.61	2.2	11.0	18.9	15.1	13	11.9	0.52	1.7	9.9	15.6	14.5	11	83	<.01	NS
H.sapiens(pooled)	13.3	0.93	2.3	11.3	17.5	17.0	6	11.5	0.78	1.9	9.3	13.9	16.6	6	87	NS	NS
Romano-British	11.4	-	-	11.3	11.4	-	2	11.6	-	-	9.3	13.8	-	2	102	-	-
Aust.Aborigines	14.3	-	-	12.9	17.5	-	4	11.5	-	-	10.4	13.9	-	4	80	-	-

G(v): Root mesiodistal diameter

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t F
$C_{\overline{1}}$																
Gorilla	13.3	0.46	1.9	10.9	19.2	14.4	17	8.2	0.28	1.0	7.1	10.3	12.1	13	62	<.001 <.05
Pan	9.6	0.22	0.9	7.7	10.6	9.0	16	7.2	0.34	1.1	5.7	9.7	15.5	11	75	<.001 NS
Pongo	10.7	0.38	0.9	9.5	12.1	8.6	6	7.5	0.21	0.6	6.2	8.1	8.3	9	70	<.001 NS
H.sapiens(pooled)	5.6	0.28	1.0	3.7	7.4	18.5	14	5.3	0.22	0.9	3.4	6.9	17.3	17	95	NS NS
Romano-British	5.3	0.34	1.0	3.7	6.6	18.9	9	5.0	0.35	1.1	3.4	6.9	23.4	10	94	NS NS
Aust.Aborigines	6.0	0.47	1.1	4.5	7.4	17.5	5	5.7	0.08	0.2	5.3	5.8	3.5	7	95	NS .001
$2RP_{\overline{3}}$ m																
Gorilla	6.1	0.15	0.7	5.0	8.0	12.0	23	5.3	0.14	0.6	4.2	6.2	10.8	16	87	.001 NS
Pan	3.9	0.17	0.7	2.8	5.1	17.4	16	4.0	0.19	0.5	3.3	4.6	11.5	6	103	NS NS
Pongo	5.3	0.19	0.8	4.0	6.7	15.2	17	4.6	0.17	0.6	3.9	5.5	12.9	13	87	<.05 NS
Aust.Aborigines	1.8	-	-	-	-	-	1	-	-	-	-	-	-	-	-	- -
$2RP_{\overline{3}}$ d																
Gorilla	5.7	0.17	0.8	4.5	7.5	14.3	23	4.9	0.15	0.6	4.1	5.8	12.4	16	86	<.01 NS
Pan	3.7	0.13	0.5	2.8	4.9	13.8	16	3.4	0.17	0.4	3.1	4.2	11.9	6	92	NS NS
Pongo	4.9	0.17	0.7	3.7	5.9	14.1	17	4.1	0.12	0.4	3.2	4.6	10.6	13	84	.001 NS
Aust.Aborigines	2.7	-	-	-	-	-	1	-	-	-	-	-	-	-	-	- -
$1RP_{\overline{3}}$																
Pan	5.8	-	-	4.9	6.5	-	4	6.3	0.36	0.8	5.6	7.6	12.7	5	109	- -
Pongo	-	-	-	-	-	-	-	6.0	-	-	-	-	-	1	-	- -
H.sapiens(pooled)	3.6	0.14	0.5	3.0	4.7	14.9	14	3.4	0.17	0.7	2.5	4.8	19.8	17	94	NS NS
Romano-British	3.3	0.08	0.3	3.0	3.7	7.4	10	3.2	0.16	0.5	2.5	3.8	15.5	10	97	NS <.05
Aust.Aborigines	4.1	-	-	3.1	4.7	-	4	3.8	0.30	0.8	2.6	4.8	20.7	7	93	- -

G(v): Root mesiodistal diameter

	Males						Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t	F
$2RP\frac{-}{4}$ m																	
Gorilla	4.0	0.07	0.3	3.1	4.5	8.5	22	3.9	0.10	0.4	3.5	4.6	9.8	15	98	NS	NS
Pan	3.2	0.09	0.4	2.7	3.9	11.9	20	3.3	0.16	0.5	2.5	4.0	15.5	10	103	NS	NS
Pongo	4.0	0.13	0.5	3.3	4.8	13.1	17	3.7	0.11	0.4	3.1	4.4	12.0	15	93	NS	NS
$2RP\frac{-}{4}$ d																	
Gorilla	4.9	0.09	0.4	4.1	5.8	8.4	22	4.8	0.15	0.6	4.0	5.9	12.4	16	98	NS	NS
Pan	3.7	0.11	0.5	2.4	4.7	13.1	20	3.7	0.15	0.5	2.8	4.5	13.2	10	100	NS	NS
Pongo	4.5	0.12	0.5	3.6	5.4	10.6	17	4.1	0.13	0.5	3.2	4.9	12.5	15	91	<.05	NS
$1RP\frac{-}{4}$																	
H.sapiens(pooled)	3.8	0.12	0.5	3.1	4.7	12.5	15	3.6	0.11	0.5	3.0	4.6	12.6	18	95	NS	NS
Romano-British	3.7	0.11	0.4	3.3	4.2	9.5	10	3.6	0.09	0.3	3.2	4.0	8.1	10	97	NS	NS
Aust.Aborigines	3.9	0.30	0.7	3.1	4.7	17.2	5	3.7	0.22	0.6	3.0	4.6	16.9	8	95	NS	NS
$M\frac{-}{1}$ m																	
Gorilla	4.6	0.18	0.9	3.5	6.9	18.4	23	4.6	0.18	0.7	3.5	6.3	16.1	17	100	NS	NS
Pan	3.9	0.10	0.5	2.9	4.8	11.8	20	3.7	0.11	0.4	3.1	4.2	9.6	11	95	NS	NS
Pongo	4.1	0.15	0.6	3.3	5.6	15.6	19	3.6	0.10	0.4	2.8	4.2	10.2	15	88	.01	<.05
H.sapiens(pooled)	4.0	0.13	0.5	2.9	4.9	12.9	16	3.6	0.18	0.7	2.6	5.5	20.8	17	90	NS	NS
Romano-British	3.9	0.21	0.7	2.9	4.9	16.5	10	3.5	0.30	1.0	2.6	5.5	26.9	10	90	NS	NS
Aust.Aborigines	4.0	0.06	0.2	3.8	4.2	3.7	6	3.6	0.11	0.3	3.2	4.1	8.4	7	90	<.01	NS

M_1 d.v. Root mesiodistal diameter

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t F
Gorilla	6.0	0.12	0.6	4.5	7.4	9.7	23	5.5	0.16	0.7	4.2	7.1	11.9	17	92	.01 NS
Pan	4.0	0.08	0.4	3.3	4.7	9.2	20	3.6	0.09	0.3	3.2	4.0	8.6	11	90	<.01 NS
Pongo	4.4	0.11	0.5	3.2	5.2	11.2	19	3.9	0.16	0.6	3.1	4.9	15.6	15	89	.01 NS
H.sapiens(pooled)	3.6	0.11	0.4	3.1	4.8	12.1	16	3.2	0.12	0.5	2.4	4.0	14.7	17	89	<.05 NS
Romano-British	3.4	0.06	0.2	3.1	3.7	5.9	10	3.3	0.18	0.6	2.4	4.0	17.2	10	97	NS <.01
Aust.Aborigines	3.9	0.22	0.5	3.3	4.8	13.8	6	3.2	0.13	0.3	2.7	3.5	10.8	7	82	<.05 NS
M_2 m																
Gorilla	5.2	0.14	0.7	4.0	6.7	13.2	23	4.9	0.21	0.9	3.8	7.5	17.3	17	94	NS NS
Pan	3.8	0.10	0.4	3.0	4.7	11.2	20	3.7	0.07	0.3	3.4	4.2	6.6	11	97	NS NS
Pongo	4.4	0.18	0.7	3.1	5.9	16.6	17	4.2	0.20	0.8	3.6	6.2	18.0	14	96	NS NS
H.sapiens(pooled)	3.4	0.11	0.4	3.0	4.3	12.6	16	3.1	0.07	0.3	2.7	3.7	10.0	17	91	<.01 NS
Romano-British	3.3	0.13	0.4	3.0	4.2	12.0	10	3.1	0.12	0.4	2.7	3.7	11.8	9	94	NS NS
Aust.Aborigines	3.7	0.18	0.4	3.1	4.3	12.1	6	3.1	0.09	0.3	2.8	3.6	8.3	8	84	<.01 NS
M_2 d																
Gorilla	6.5	0.16	0.8	5.3	7.9	11.8	23	5.7	0.12	0.5	4.9	6.6	8.6	16	88	.001 NS
Pan	3.9	0.10	0.5	3.0	4.9	11.5	20	3.8	0.12	0.4	3.2	4.4	10.0	11	97	NS NS
Pongo	5.0	0.12	0.5	4.4	5.9	9.1	15	4.6	0.19	0.7	3.4	6.1	14.6	13	92	NS NS
H.sapiens(pooled)	3.7	0.15	0.6	2.9	5.3	16.3	16	3.5	0.09	0.4	3.0	4.4	10.1	17	95	NS <.05
Romano-British	3.5	0.11	0.3	3.0	4.0	9.9	10	3.5	0.15	0.4	3.0	4.4	12.5	9	100	NS NS
Aust.Aborigines	4.0	0.33	0.8	2.9	5.3	20.0	6	3.4	0.08	0.2	3.0	3.6	6.3	8	85	NS <.01

GLV): Root mesiodistal diameter

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t	F
M_3 m																	
Gorilla	5.1	0.11	0.5	4.2	6.4	10.3	22	4.8	0.17	0.7	3.5	5.9	14.0	15	94	NS	NS
Pan	3.9	0.14	0.6	3.0	5.3	15.5	20	3.8	0.13	0.5	2.9	4.5	11.8	11	97	NS	NS
Pongo	4.4	0.13	0.5	3.7	5.0	10.5	13	4.0	0.09	0.4	3.4	4.6	9.2	7	91	NS	NS
H.sapiens(pooled)	3.6	0.17	0.6	2.5	4.5	17.4	13	3.6	0.09	0.3	3.1	4.4	9.5	14	100	NS	<.05
Romano-British	3.3	0.29	0.5	2.5	4.0	16.2	8	3.7	0.16	0.4	3.2	4.4	11.1	7	112	NS	NS
Aust.Aborigines	4.2	0.13	0.3	3.7	4.5	7.1	5	3.5	0.09	0.3	3.1	3.9	7.0	7	83	<.01	NS
M_3 d																	
Gorilla	6.1	0.18	0.8	4.8	8.0	12.6	19	5.9	0.23	0.8	4.7	7.7	14.1	13	97	NS	NS
Pan	4.1	0.11	0.5	3.1	5.2	12.1	19	3.8	0.17	0.6	3.1	4.7	14.4	10	93	NS	NS
Pongo	4.6	0.22	0.8	3.4	5.6	16.9	12	4.9	0.14	0.8	4.0	6.4	17.3	7	107	NS	NS
H.sapiens(pooled)	3.5	0.22	0.8	2.3	5.1	23.1	13	3.7	0.13	0.5	3.1	4.5	12.6	14	106	NS	NS
Romano-British	3.1	0.21	0.6	2.3	4.3	19.2	8	3.7	0.20	0.5	3.1	4.5	14.6	7	119	NS	NS
Aust.Aborigines	4.1	0.35	0.8	3.2	5.1	19.1	5	3.8	0.16	0.4	3.1	4.3	11.3	7	93	NS	NS
$3RP^3$ l																	
Gorilla	7.6	0.25	1.2	5.6	10.6	15.6	22	6.9	0.22	0.9	5.6	9.2	12.9	17	91	NS	NS
Pan	4.2	0.15	0.7	3.2	5.3	15.5	18	4.0	0.20	0.6	2.7	4.7	14.6	9	95	NS	NS
Pongo	5.3	0.17	0.7	4.2	6.4	12.4	14	4.6	0.16	0.5	4.1	5.6	10.8	10	87	<.05	NS
$3RP^3$ mb																	
Gorilla	5.6	0.24	1.1	3.8	8.4	20.1	22	5.1	0.24	1.0	3.8	7.2	19.7	17	91	NS	NS
Pan	3.4	0.16	0.7	2.2	4.7	19.2	18	3.8	0.17	0.5	2.9	4.4	12.9	9	112	NS	NS
Pongo	4.2	0.21	0.8	2.6	5.7	18.8	14	3.7	0.22	0.7	2.6	4.9	18.8	10	88	NS	NS

G(V): Root mesiodistal diameter

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t F
$3RP^3$ db																
Gorilla	3.7	0.10	0.5	2.7	4.4	12.7	22	3.4	0.12	0.5	2.8	4.6	15.0	17	92	NS NS
Pan	2.9	0.19	0.5	2.2	4.3	17.5	18	2.7	0.12	0.4	2.0	3.3	13.3	9	93	NS NS
Pongo	3.0	0.10	0.4	2.6	4.0	12.5	14	3.0	0.15	0.5	2.3	3.6	15.6	10	100	NS NS
$2RP^3$ 1																
Pan	3.8	-	-	-	-	-	1	4.2	-	-	3.4	4.9	-	2	-	- -
Pongo	-	-	-	-	-	-	-	4.6	-	-	4.2	4.9	-	2	-	- -
H.sapiens(pooled)	3.7	-	-	3.3	4.2	-	4	3.3	-	-	-	-	-	1	-	- -
Romano-British	3.6	-	-	3.3	3.8	-	3	-	-	-	-	-	-	-	-	- -
Aust.Aborigines	4.2	-	-	-	-	-	1	3.3	-	-	-	-	-	1	-	- -
$2RP^3$ b																
Pan	4.8	-	-	-	-	-	1	4.9	-	-	4.5	5.2	-	2	-	- -
Pongo	-	-	-	-	-	-	-	4.9	-	-	4.5	5.2	-	2	-	- -
H.sapiens(pooled)	3.3	-	-	2.9	3.9	-	4	3.4	-	-	-	-	-	1	-	- -
Romano-British	3.1	-	-	2.9	3.4	-	3	-	-	-	-	-	-	-	-	- -
Aust.Aborigines	3.9	-	-	-	-	-	1	3.4	-	-	-	-	-	1	-	- -
$1RP^3$																
H.sapiens(pooled)	3.8	0.12	0.4	2.9	4.4	10.8	12	3.4	0.12	0.4	2.9	4.2	12.9	14	90	<.05 NS
Romano-British	3.6	0.14	0.4	2.9	4.0	10.6	7	3.2	0.14	0.4	2.9	3.9	12.1	8	89	NS NS
Aust.Aborigines	4.1	0.10	0.2	3.9	4.4	5.2	5	3.8	0.13	0.3	3.4	4.2	8.2	6	93	NS NS

G(v): Root mesiodistal diameter

	Males							Females							%SD	P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N		t	F
$3RP^4$ l																	
Gorilla	8.0	0.21	1.0	6.3	9.9	12.6	23	7.5	0.26	1.1	6.4	10.1	14.5	17	94	NS	NS
Pan	4.5	-	-	4.4	4.6	-	3	4.0	-	-	2.8	5.2	-	2	89	-	-
Pongo	5.3	0.19	0.7	3.8	6.9	13.9	16	5.1	0.23	0.8	4.1	6.0	14.9	11	96	NS	NS
$3RP^4$ mb																	
Gorilla	4.0	0.13	0.6	3.0	5.6	15.3	23	3.8	0.20	0.8	2.7	5.6	21.4	17	95	NS	NS
Pan	2.7	-	-	2.5	2.9	-	3	2.3	-	-	2.0	2.5	-	2	85	-	-
Pongo	3.3	0.12	0.5	2.6	4.1	15.0	16	3.1	0.08	0.3	2.7	3.4	8.1	11	94	NS	<.05
$3RP^4$ db																	
Gorilla	3.6	0.10	0.5	2.9	4.8	12.7	23	3.4	0.10	0.4	2.6	4.1	11.9	17	94	NS	NS
Pan	2.7	-	-	2.6	2.8	-	3	2.5	-	-	2.3	2.7	-	2	93	-	-
Pongo	3.5	0.11	0.4	3.0	4.3	12.3	16	3.1	0.10	0.3	2.6	3.7	10.9	11	89	<.05	NS
$2RP^4$ l																	
Pan	4.5	0.18	0.7	3.3	6.3	16.6	17	44.1	0.19	0.5	3.4	5.2	12.9	8	91	NS	NS
Pongo	5.3	-	-	-	-	-	1	4.1	-	-	-	-	-	1	-	-	-
$2PP^4$ b																	
Pan	3.8	0.16	0.6	2.8	5.0	16.7	17	4.0	0.20	0.6	3.3	4.8	14.2	8	105	NS	NS
Pongo	4.1	-	-	-	-	-	1	4.1	-	-	-	-	-	1	-	-	-
$1RP^4$																	
H.sapiens(pooled)	3.7	0.11	0.4	3.0	4.6	11.6	16	3.4	0.11	0.4	2.6	4.3	12.8	16	92	NS	NS
Romano-British	3.5	0.10	0.3	3.0	4.1	9.1	10	3.3	0.16	0.5	2.6	4.0	14.3	9	94	NS	NS
Aust.Aborigines	4.1	0.15	0.4	3.6	4.6	9.3	6	3.6	0.14	0.4	3.1	4.3	10.0	7	88	NS	NS

G (v): Root mesiodistal diameter

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t F
M^1 l																
Gorilla	10.0	0.25	1.2	8.0	12.1	11.8	23	8.8	0.21	0.9	7.5	10.4	10.0	17	88	<.01 NS
Pan	5.2	0.17	0.7	3.2	6.1	14.1	20	4.9	0.15	0.5	4.1	5.7	9.9	11	94	NS NS
Pongo	7.2	0.15	0.6	6.0	8.8	8.9	18	6.8	0.19	0.7	5.4	8.2	10.5	14	94	NS NS
H.sapiens(pooled)	5.0	0.18	0.7	3.7	6.1	13.8	15	4.7	0.16	0.7	3.5	6.1	14.0	16	94	NS NS
Romano-British	4.7	0.17	0.5	3.7	5.5	11.4	10	4.4	0.21	0.6	3.5	5.1	13.7	8	94	NS NS
Aust.Aborigines	5.5	0.32	0.7	4.3	6.1	13.1	5	4.9	0.22	0.6	4.0	6.1	12.8	8	89	NS NS
M^1 mb																
Gorilla	4.4	0.12	0.6	3.0	5.6	13.1	23	4.0	0.16	0.7	2.9	5.8	16.4	17	91	NS NS
Pan	3.2	0.09	0.4	2.3	3.7	13.1	20	3.2	0.14	0.5	2.4	4.0	14.2	11	100	NS NS
Pongo	3.7	0.11	0.5	2.9	4.5	12.4	18	3.5	0.11	0.4	2.7	4.0	12.0	14	95	NS NS
H.sapiens(pooled)	3.3	0.14	0.5	2.4	4.6	16.4	15	3.1	0.09	0.4	2.6	4.1	12.2	16	94	NS NS
Romano-British	3.2	0.12	0.4	2.4	3.8	12.0	10	2.9	0.08	0.2	2.7	3.2	7.5	8	91	NS NS
Aust.Aborigines	3.6	0.32	0.7	2.7	4.6	19.9	5	3.2	0.16	0.5	2.6	4.1	14.5	8	89	NS NS
M^1 db																
Gorilla	4.8	0.15	0.7	3.6	6.3	14.5	23	4.3	0.11	0.5	3.6	5.2	10.8	17	90	<.05 NS
Pan	3.1	0.11	0.5	2.4	4.1	15.2	20	3.1	0.09	0.3	2.8	3.8	9.6	11	100	NS NS
Pongo	3.7	0.15	0.6	2.8	4.9	17.4	18	3.3	0.10	0.4	2.6	4.0	11.5	14	89	NS NS
H.sapiens(pooled)	3.1	0.08	0.3	2.6	3.6	9.6	15	2.8	0.11	0.4	2.1	3.6	15.2	16	90	<.05 NS
Romano-British	3.0	0.09	0.3	2.6	3.3	8.9	10	2.7	0.15	0.4	2.1	3.1	15.2	8	90	NS NS
Aust.Aborigines	3.3	0.18	0.3	3.0	3.6	7.8	5	3.0	0.15	0.4	2.4	3.6	14.7	8	91	NS NS

G(v): Root mesiodistal diameter

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t	F
M^2 l																	
Gorilla	11.7	0.29	1.3	9.0	14.2	11.5	21	10.2	0.39	1.5	7.8	13.6	15.1	15	87	<.01	NS
Pan	5.5	0.19	0.8	4.3	6.9	15.3	20	5.0	0.19	0.6	4.1	5.9	12.3	10	91	NS	NS
Pongo	7.5	0.20	0.8	5.6	9.0	10.0	14	7.0	0.21	0.8	6.1	9.0	11.8	15	93	NS	NS
H.sapiens(pooled)	4.5	0.19	0.8	3.5	6.0	16.7	15	4.4	0.17	0.6	3.3	5.7	13.8	13	98	NS	NS
Romano-British	4.3	0.25	0.7	3.5	6.0	17.3	9	4.0	0.19	0.4	3.3	4.4	11.0	5	93	NS	NS
Aust.Aborigines	4.8	0.29	0.7	3.6	5.8	15.0	6	4.7	0.19	0.5	4.1	5.7	11.1	8	98	NS	NS
M^2 mb																	
Gorilla	4.7	0.17	0.8	3.6	6.7	16.6	21	4.2	0.13	0.5	3.4	5.3	12.2	15	89	<.05	NS
Pan	3.2	0.10	0.4	2.4	4.0	13.6	20	3.2	0.16	0.5	2.6	4.0	15.9	10	100	NS	NS
Pongo	3.8	0.10	0.4	3.0	4.5	9.8	14	3.9	0.09	0.4	3.1	4.5	9.3	15	103	NS	NS
H.sapiens(pooled)	3.2	0.11	0.4	2.6	3.8	13.1	15	2.9	0.11	0.4	2.2	3.6	13.0	13	91	NS	NS
Romano-British	3.1	0.14	0.4	2.6	3.8	13.9	9	2.6	0.14	0.3	2.2	3.0	12.2	5	84	<.05	NS
Aust.Aborigines	3.2	0.17	0.4	2.8	3.8	12.8	6	3.1	0.09	0.3	2.9	3.6	8.3	8	97	NS	NS
M^2 db																	
Gorilla	4.9	0.18	0.8	3.6	6.7	16.9	21	4.8	0.18	0.7	3.5	6.4	14.8	15	98	NS	NS
Pan	2.8	0.09	0.4	2.1	3.5	13.5	20	3.1	0.08	0.3	2.8	3.4	8.1	10	111	NS	NS
Pongo	3.9	0.14	0.5	3.1	4.9	13.9	14	3.5	0.09	0.4	3.0	4.4	10.2	15	90	NS	NS
H.sapiens(pooled)	3.1	0.11	0.4	2.6	3.8	13.4	15	2.9	0.13	0.5	2.2	3.6	16.3	13	94	NS	NS
Romano-British	3.0	0.12	0.4	2.6	3.5	12.3	9	2.8	0.23	0.5	2.2	3.6	18.9	5	93	NS	NS
Aust.Aborigines	3.2	0.20	0.5	2.6	3.8	15.0	6	2.9	0.16	0.5	2.2	3.5	15.6	8	91	NS	NS

G(v) : Root mesiodistal diameter

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t	F
M^3 l																	
Gorilla	9.4	0.25	1.2	6.8	11.1	12.8	23	7.9	0.33	1.2	6.4	10.6	15.4	14	84	.001	NS
Pan	4.7	0.13	0.6	3.4	6.1	12.7	20	4.5	0.18	0.6	3.5	5.3	12.4	10	96	NS	NS
Pongo	6.9	0.26	0.9	5.3	8.4	13.6	13	7.0	0.23	0.8	5.1	7.7	10.7	11	102	NS	NS
H.sapiens(pooled)	4.4	0.25	0.6	3.5	5.2	13.7	6	4.4	0.38	0.9	2.9	5.8	21.1	6	100	NS	NS
Romano-British	3.9	-	-	3.5	4.3	-	2	4.5	-	-	4.4	4.5	-	2	115	-	-
Aust.Aborigines	4.7	-	-	4.2	5.2	-	4	4.4	-	-	2.9	5.8	-	4	94	-	-
M^3 mb																	
Gorilla	4.4	0.11	0.5	3.7	5.5	12.2	23	4.2	0.19	0.7	2.7	5.4	16.6	14	96	NS	NS
Pan	3.1	0.10	0.5	2.4	4.3	15.2	20	2.9	0.14	0.5	2.2	3.7	15.6	10	94	NS	NS
Pongo	3.5	0.16	0.6	2.7	4.7	16.3	13	3.7	0.09	0.3	3.2	4.1	7.8	11	106	NS	<.05
H.sapiens(pooled)	3.4	0.30	0.7	2.7	4.4	21.2	6	2.9	0.13	0.3	2.5	3.4	11.1	6	85	NS	NS
Romano-British	2.8	-	-	2.7	2.9	-	2	2.7	-	-	2.5	2.9	-	2	96	-	-
Aust.Aborigines	3.7	-	-	2.8	4.4	-	4	3.1	-	-	2.7	3.4	-	4	84	-	-
M^3 db																	
Gorilla	4.5	0.18	0.9	3.1	6.0	19.5	23	3.8	0.18	0.7	2.9	5.1	17.1	14	84	<.05	NS
Pan	2.7	0.11	0.5	2.1	3.7	17.5	20	3.0	0.17	0.5	2.2	4.1	17.8	10	111	NS	NS
Pongo	3.8	0.20	0.7	2.4	4.9	19.2	13	3.7	0.16	0.5	2.9	4.7	14.6	11	97	NS	NS
H.sapiens(pooled)	2.8	0.14	0.3	2.4	3.2	12.0	6	2.7	0.20	0.5	2.3	3.6	18.1	6	96	NS	NS
Romano-British	2.7	-	-	2.5	2.8	-	2	2.3	-	-	2.3	2.3	-	2	85	-	-
Aust.Aborigines	2.9	-	-	2.4	3.2	-	4	2.9	-	-	2.5	3.6	-	4	100	-	-

G(V1): Height of bifurcation

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t	F
$2RP_{\bar{3}}$																	
Gorilla	4.9	0.47	2.3	1.7	11.7	46.7	23	4.5	0.35	1.5	1.9	7.1	32.2	17	92	NS	NS
Pan	4.6	0.46	1.8	2.4	9.7	39.7	16	5.2	0.65	1.6	3.2	7.9	30.6	6	113	NS	NS
Pongo	6.9	0.45	2.0	2.5	10.6	28.4	19	5.4	0.44	1.6	2.7	9.0	30.4	14	78	<.05	NS
Aust.Aborigines	7.8	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
$2RP_{\bar{4}}$																	
Gorilla	6.1	0.26	1.2	4.5	9.3	20.4	22	5.6	0.25	1.0	3.2	7.6	18.6	17	92	NS	NS
Pan	5.4	0.25	1.1	4.1	7.8	20.9	20	5.4	0.78	2.6	2.7	12.3	47.5	11	100	NS	<.01
Pongo	5.1	0.28	1.2	3.6	8.9	24.0	19	5.0	0.33	1.3	3.3	8.0	26.0	15	98	NS	NS
$M_{\bar{1}}$																	
Gorilla	3.6	0.16	0.8	2.5	5.5	20.9	23	3.4	0.14	0.6	2.4	4.5	16.7	17	94	NS	NS
Pan	3.3	0.13	0.6	2.2	4.8	18.0	20	3.1	0.12	0.4	2.6	4.0	12.4	11	94	NS	NS
Pongo	4.5	0.17	0.8	3.2	5.8	16.9	19	3.8	0.17	0.7	2.8	5.0	17.2	15	84	<.01	NS
H.sapiens(pooled)	4.3	0.15	0.6	3.4	5.4	13.8	16	4.1	0.16	0.6	3.1	5.7	15.8	17	95	NS	NS
Romano-British	4.2	0.17	0.5	3.5	5.4	12.7	10	4.2	0.24	0.8	3.1	5.7	18.3	10	100	NS	NS
Aust.Aborigines	4.5	0.28	0.7	3.4	5.3	15.2	6	3.9	0.13	0.4	3.4	4.3	9.2	7	87	<.05	NS
$M_{\bar{2}}$																	
Gorilla	4.2	0.17	0.8	3.1	6.1	19.6	23	4.0	0.19	0.8	2.6	5.8	18.9	17	95	NS	NS
Pan	3.6	0.18	0.8	1.9	5.1	22.7	20	3.2	0.08	0.3	2.6	3.6	8.3	11	89	NS	.001
Pongo	4.8	0.19	0.8	3.6	6.6	17.1	19	4.2	0.23	0.9	2.8	5.7	21.2	15	88	<.05	NS
H.sapiens(pooled)	4.4	0.16	0.7	3.2	5.6	14.5	16	4.1	0.16	0.7	3.4	5.6	15.9	17	93	NS	NS
Romano-British	4.2	0.18	0.6	3.2	5.4	13.6	10	4.2	0.19	0.6	3.5	5.3	13.8	9	100	NS	NS
Aust.Aborigines	4.8	0.26	0.7	3.9	5.6	13.4	6	4.0	0.26	0.7	3.4	5.6	18.7	8	83	<.05	NS

G(vi): Height of bifurcation

	Males							Females								P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t	F
M$_3$																	
Gorilla	3.9	0.17	0.8	2.4	5.5	20.0	23	3.8	0.16	0.6	2.7	4.8	16.8	16	97	NS	NS
Pan	3.7	0.21	0.9	2.0	5.9	24.7	20	2.9	0.21	0.7	1.5	3.7	23.4	11	78	<.05	NS
Pongo	4.6	0.18	0.8	2.9	5.8	17.5	19	4.1	0.19	0.7	2.6	5.0	18.1	15	89	NS	NS
H.sapiens(pooled)	4.4	0.23	0.9	3.4	5.8	19.8	14	4.6	0.26	1.0	3.0	7.3	20.8	14	105	NS	NS
Romano-British	4.1	0.27	0.8	3.4	5.6	18.9	8	4.2	0.29	0.8	3.0	5.1	17.9	7	102	NS	NS
Aust.Aborigines	4.9	0.35	0.9	3.7	5.8	17.4	6	5.0	0.39	1.0	4.2	7.3	20.7	7	102	NS	NS
3RP^3																	
Gorilla	5.3	0.28	1.3	2.7	8.0	24.8	22	4.7	0.50	2.1	1.6	7.7	43.8	17	89	NS	<.05
Pan	4.6	0.32	1.4	2.0	6.5	29.6	18	5.2	0.40	1.2	3.3	7.4	23.1	9	113	NS	NS
Pongo	6.4	0.52	1.9	4.7	11.5	30.0	14	5.7	0.37	1.2	3.9	7.3	20.4	10	89	NS	NS
3PP^4																	
Gorilla	5.3	0.29	1.4	2.3	8.0	26.3	23	4.9	0.28	1.2	3.1	7.9	23.4	17	93	NS	NS
Pan	4.0	-	-	3.0	5.9	-	3	3.9	-	-	3.0	4.8	-	2	98	-	-
Pongo	6.0	0.46	1.8	3.7	9.5	30.8	16	5.6	0.31	1.0	3.4	6.8	18.4	11	93	NS	NS
M^1																	
Gorilla	3.0	0.26	1.2	1.3	6.9	41.4	23	2.8	0.29	1.2	0.8	4.8	42.4	17	93	NS	NS
Pan	2.7	0.22	1.0	1.3	4.6	35.5	20	3.0	0.29	1.0	1.6	4.4	32.0	11	111	NS	NS
Pongo	4.1	0.29	1.2	2.2	6.5	29.6	18	3.6	0.25	1.0	2.5	5.3	26.2	14	88	NS	NS
H.sapiens(pooled)	4.3	0.26	1.0	2.6	5.5	32.2	15	3.6	0.21	0.9	2.3	5.2	23.5	16	84	<.05	NS
Romano-British	4.3	0.38	1.2	2.6	5.5	27.8	10	3.5	0.33	0.9	2.3	4.7	27.2	8	81	NS	NS
Aust.Aborigines	4.3	0.22	0.5	3.8	5.0	11.3	5	3.8	0.28	0.8	2.8	5.2	20.4	8	88	NS	NS

G(v1): Height of bifurcation

	Males							Females								P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t	F
M^2																	
Gorilla	3.2	0.31	1.4	1.1	6.4	43.6	21	3.1	0.28	1.1	0.9	5.0	35.4	15	97	NS	NS
Pan	2.9	0.21	0.9	1.2	4.6	32.0	20	3.2	0.48	1.5	0.9	5.5	48.1	10	110	NS	NS
Pongo	4.1	0.32	1.2	2.4	6.7	28.6	14	3.4	0.19	0.7	2.4	5.4	21.4	15	83	NS	NS
H.sapiens(pooled)	4.8	0.35	1.4	2.7	7.1	28.4	15	4.4	0.18	0.6	3.4	5.2	14.5	13	92	NS	<.05
Romano-British	4.7	0.48	1.5	2.9	7.1	31.0	9	4.5	0.29	0.6	3.8	5.2	14.1	5	96	NS	NS
Aust.Aborigines	5.0	0.55	1.3	2.7	6.2	26.6	6	4.3	0.23	0.7	3.4	5.0	15.2	8	86	NS	NS
M^3																	
Gorilla	3.3	0.28	1.3	1.1	5.9	40.4	23	3.5	0.36	1.4	1.4	5.7	38.9	14	106	NS	NS
Pan	3.4	0.19	0.9	1.9	4.6	25.7	20	3.5	0.29	0.9	2.2	4.7	26.5	10	103	NS	NS
Pongo	3.9	0.43	1.5	1.6	6.5	39.5	13	3.0	0.26	0.9	1.7	4.2	28.3	11	77	NS	NS
H.sapiens(pooled)	4.7	0.47	1.1	3.5	6.4	24.2	6	4.8	0.50	1.2	3.2	6.4	25.2	6	102	NS	NS
Romano-British	3.9	-	-	3.7	4.1	-	2	4.8	-	-	3.2	6.4	-	2	123	-	-
Aust.Aborigines	5.1	-	-	3.5	6.4	-	4	4.8	-	-	3.8	5.9	-	4	94	-	-

G(vii): Root angulation

	Males						Females						P	
	$\bar{X}$	S.E.	S.D.	min	max	N	$\bar{X}$	S.E.	S.D.	min	max	N	t	F
$I_{\frac{1}{1}}$														
Gorilla	+4	1.24	4.8	-4	+14	15	+1	0.97	3.5	-5	+6	13	NS	NS
Pan	+5	1.41	5.8	-6	+19	17	+5	1.48	4.4	-2	+12	9	NS	NS
Pongo	+2	0.83	3.3	-2	+9	16	+2	0.78	3.0	-3	+8	15	NS	NS
H.sapiens(pooled)	-1	1.29	4.3	-8	+7	11	-2	0.95	3.6	-11	+2	14	NS	NS
Romano-British	0	1.45	4.1	-5	+7	8	-1	1.38	4.2	-11	+2	9	NS	NS
Aust.Aborigines	-4	-	-	-8	0	3	-2	0.98	2.2	-5	+1	5	-	-
$I_{\frac{2}{2}}$														
Gorilla	+14	1.06	4.7	+5	+22	20	+12	1.26	5.0	+4	+20	16	NS	NS
Pan	+13	0.87	3.6	+6	+20	17	+11	1.79	5.4	+3	+20	9	NS	NS
Pongo	+10	1.67	6.9	+2	+24	17	+11	1.07	4.0	+5	+17	14	NS	NS
H.sapiens(pooled)	+4	1.46	5.5	-5	+17	14	+2	1.09	4.4	-5	+10	16	NS	NS
Romano-British	+5	1.95	6.2	-5	+17	10	0	0.71	2.2	-3	+4	10	<.05	<.01
Aust.Aborigines	+3	-	-	-2	+7	4	+4	2.35	5.6	-5	+10	6	-	-
$2RP_{\frac{3}{3}}$ m														
Gorilla	-6	1.13	5.4	-18	+4	23	-6	1.06	4.2	-14	0	16	NS	NS
Pan	-7	1.31	5.3	-15	+3	16	-4	1.43	3.5	-8	+1	6	NS	NS
Pongo	-5	1.26	5.2	-13	+4	17	-7	1.35	4.9	-16	+2	13	NS	NS
Aust.Aborigines	-8	-	-	-	-	1	-	-	-	-	-	-	-	-

G(vii): Root angulation

	Males						Females						P	
	$\bar{X}$	S.E.	S.D.	min	max	N	$\bar{X}$	S.E.	S.D.	min	max	N	t	F
$2RP\frac{-}{3}$ d														
Gorilla	-1	0.87	4.2	-8	+8	23	+2	1.09	4.4	-6	+10	16	NS	NS
Pan	-5	0.95	3.8	-12	+2	16	-4	0.76	1.9	-6	--1	6	NS	NS
Pongo	-5	1.02	4.2	-11	+1	17	-8	1.20	4.3	-16	-2	13	NS	NS
Aust.Aborigines	-2	-	-	-	-	1	-	-	-	-	-	-	-	-
$1RP\frac{-}{3}$														
Pan	-9	-	-	-16	+1	4	-4	2.86	6.4	-15	-1	5	-	-
Pongo	-	-	-	-	-	-	-6	-	-	-	-	1	-	-
H.sapiens(pooled)	-4	0.99	3.7	-14	+1	14	-5	0.76	3.1	-9	+3	17	NS	NS
Romano-British	-3	0.78	2.5	-6	+1	10	-4	0.98	3.1	-8	+3	10	NS	NS
Aust.Aborigines	-8	-	-	-14	-5	4	-5	1.26	3.3	-9	-1	7	-	-
$2RP\frac{-}{4}$ m														
Gorilla	-2	0.83	3.9	-8	+6	22	-2	0.97	3.8	-8	+7	15	NS	NS
Pan	-2	0.91	4.1	-10	+6	20	-1	1.46	4.9	-9	+8	11	NS	NS
Pongo	-4	1.18	4.9	-13	+6	17	-5	1.19	4.6	-14	+2	15	NS	NS
$2RP\frac{-}{4}$ d														
Gorilla	-6	0.74	3.5	-11	+1	22	-6	0.81	3.2	-11	+2	16	NS	NS
Pan	-9	0.99	4.4	-16	-2	20	-5	0.91	3.0	-9	+1	11	<.01	NS
Pongo	-9	0.84	3.5	-14	-3	17	-9	1.24	4.8	-17	-1	15	NS	NS

G(vii): Root angulation

	Males						Females						P	
	$\bar{X}$	S.E.	S.D.	min	max	N	$\bar{X}$	S.E.	S.D.	min	max	N	t	F
$IRP_{\overline{4}}$														
H.sapiens(pooled)	-3	0.50	2.0	-8	-1	15	-4	0.44	1.9	-7	-1	18	NS	NS
Romano-British	-3	0.40	1.3	-5	-1	10	-4	0.59	1.9	-7	-1	10	NS	NS
Aust.Aborigines	-5	1.17	2.6	-8	-1	5	-4	0.68	1.9	-7	-1	8	NS	NS
$M_{\overline{1}}$ m														
Gorilla	-3	0.91	4.3	-10	+4	23	-4	0.84	3.5	-13	+2	17	NS	NS
Pan	-1	0.84	3.7	-7	+6	20	-3	0.73	2.4	-6	0	11	NS	NS
Pongo	-5	0.95	4.1	-13	+2	19	-6	0.77	3.0	-11	-1	15	NS	NS
H.sapiens(pooled)	-4	1.14	4.6	-10	+3	16	-4	1.09	4.5	-13	+5	17	NS	NS
Romano-British	-3	1.49	4.7	-10	+3	10	-2	1.32	4.2	-10	+5	10	NS	NS
Aust.Aborigines	-6	1.56	3.8	-10	0	6	-7	1.28	3.4	-13	-4	7	NS	NS
$M_{\overline{1}}$ d														
Gorilla	-16	1.24	5.9	-28	-8	23	-17	0.72	3.0	-21	-12	17	NS	<.01
Pan	-12	1.07	4.8	-24	-2	20	-9	0.96	3.2	-13	-2	11	<.05	NS
Pongo	-12	0.76	3.3	-19	-7	19	-13	0.97	3.8	-19	-4	15	NS	NS
H.sapiens(pooled)	-12	0.75	3.0	-20	-7	16	-11	0.76	3.1	-17	-6	17	NS	NS
Romano-British	-13	1.06	3.3	-20	-8	10	-13	1.01	3.2	-17	-7	10	NS	NS
Aust.Aborigines	-12	1.07	2.6	-14	-7	6	-9	0.64	1.7	-11	-6	7	<.05	NS

G(vii): Root angulation

	Males						Females						P	
	$\bar{X}$	S.E.	S.D.	min	max	N	$\bar{X}$	S.E.	S.D.	min	max	N	t	F
M_2 m														
Gorilla	-3	0.66	3.2	-9	+2	23	-6	0.94	3.9	-13	+1	17	<.01	NS
Pan	-2	0.74	3.3	-7	+5	20	+1	1.19	3.9	-5	+7	11	NS	NS
Pongo	-2	0.77	3.2	-6	+4	17	-4	1.21	4.5	-11	+4	14	NS	NS
H.sapiens(pooled)	-8	0.84	3.4	-14	-2	16	-8	0.98	4.1	-17	-2	17	NS	NS
Romano-British	-9	1.00	3.2	-14	-4	10	-7	1.14	3.4	-13	-3	9	NS	NS
Aust.Aborigines	-8	1.62	4.0	-13	-2	6	-10	1.59	4.5	-17	-2	8	NS	NS
M_2 d														
Gorilla	-14	0.99	4.7	-22	-5	23	-16	0.83	3.3	-22	-11	16	NS	NS
Pan	-10	0.77	3.5	-17	-5	20	-9	0.92	3.1	-14	-4	11	NS	NS
Pongo	-9	0.67	2.6	-15	-6	15	-12	0.87	3.1	-18	-7	13	<.05	NS
H.sapiens(pooled)	-8	0.96	3.9	-14	0	16	-9	1.04	4.3	-18	0	17	NS	NS
Romano-British	-9	0.90	2.9	-12	-5	10	-10	1.40	4.2	-18	-5	9	NS	NS
Aust.Aborigines	-6	1.98	4.9	-14	0	6	-7	1.48	4.2	-13	0	8	NS	NS
M_3 m														
Gorilla	-5	0.82	3.9	-13	+3	22	-5	0.58	2.2	-11	-3	15	NS	<.05
Pan	0	1.34	6.0	-13	+13	20	+2	1.47	4.9	-6	+8	11	NS	NS
Pongo	-4	0.85	3.1	-9	+2	13	-4	1.86	4.9	-10	+4	7	NS	NS
H.sapiens(pooled)	-9	1.38	5.0	-19	-2	13	-8	1.65	6.2	-18	+2	14	NS	NS
Romano-British	-10	1.92	5.4	-19	-2	8	-10	2.38	6.3	-18	-1	7	NS	NS
Aust.Aborigines	-8	1.97	4.4	-13	-2	5	-6	2.19	5.8	-13	+2	7	NS	NS

G(vii): Root angulation

	Males						Females						P	
	$\bar{X}$	S.E.	S.D.	min	max	N	$\bar{X}$	S.E.	S.D.	min	max	N	t	F
M_3 d														
Gorilla	-23	1.34	5.8	-38	-13	19	-19	1.38	5.0	-26	-10	13	NS	NS
Pan	-14	1.54	6.7	-24	-2	19	-14	1.02	3.2	-18	-8	10	NS	<.05
Pongo	-13	1.25	4.3	-23	-8	12	-16	1.25	3.3	-20	-12	7	NS	NS
H.sapiens(pooled)	-7	1.47	5.3	-14	+5	13	-6	1.65	6.2	-23	+1	14	NS	NS
Romano-British	-7	2.14	6.1	-14	+5	8	-9	2.75	7.3	-23	-2	7	NS	NS
Aust.Aborigines	-7	1.99	4.4	-13	-2	5	-3	1.20	3.2	-8	+1	7	NS	NS
I^1														
Gorilla	-1	0.87	3.7	-9	+4	18	-4	1.17	4.2	-10	+3	13	NS	NS
Pan	-4	1.31	5.4	-11	+10	17	-3	1.81	6.0	-11	+7	11	NS	NS
Pongo	-2	0.93	3.8	-5	+7	17	-1	1.74	6.0	-9	+12	12	NS	NS
H.sapiens(pooled)	-3	1.11	3.8	-10	+2	12	-1	1.01	3.6	-7	+4	13	NS	NS
Romano-British	-3	1.27	4.0	-10	+2	10	-1	1.31	3.9	-7	+4	9	NS	NS
Aust.Aborigines	-1	-	-	-2	+1	2	-2	-	-	-5	+3	4	-	-
I^2														
Gorilla	+6	1.51	5.7	-7	+13	14	+5	2.64	8.8	-6	+20	11	NS	NS
Pan	+5	1.46	5.5	-4	+17	14	+4	1.79	5.7	-5	+12	10	NS	NS
Pongo	+5	1.57	6.7	-11	+12	18	+3	1.04	3.6	-4	+10	12	NS	<.05
H.sapiens(pooled)	+2	0.81	3.0	-5	+5	14	+2	1.09	4.2	-4	+11	15	NS	NS
Romano-British	+2	0.71	2.1	-1	+5	9	+4	1.33	3.8	0	+11	8	NS	NS
Aust.Aborigines	+1	1.97	4.4	-5	+5	5	0	1.62	4.3	-4	+9	7	NS	NS

G(vii): Root angulation

	Males						Females						P	
	$\bar{X}$	S.E.	S.D.	min	max	N	$\bar{X}$	S.E.	S.D.	min	max	N	t	F
$3RP^{\underline{3}}$ l														
Gorilla	-5	0.84	3.9	-15	+1	22	-3	0.95	3.9	-8	+10	17	NS	NS
Pan	-7	1.07	4.5	-13	+3	18	-5	1.38	4.2	-10	+1	9	NS	NS
Pongo	-9	1.32	4.9	-15	+5	14	-9	2.16	6.8	-23	0	10	NS	NS
$3RP^{\underline{3}}$ mb														
Gorilla	+2	1.44	6.8	-11	+17	22	-1	1.14	4.7	-7	+9	17	NS	NS
Pan	-1	1.04	4.4	-9	+8	18	+1	2.18	6.5	-9	+11	9	NS	NS
Pongo	0	1.42	5.3	-11	+7	14	0	2.25	7.1	-14	+10	10	NS	NS
$3RP^{\underline{3}}$ db														
Gorilla	-9	1.43	6.7	-22	+2	22	-9	1.75	7.2	-21	+3	17	NS	NS
Pan	-12	1.51	6.4	-28	-3	18	-10	2.10	6.3	-20	-2	9	NS	NS
Pongo	-9	1.44	5.4	-17	+2	14	-9	2.41	7.6	-26	+1	10	NS	NS
$2RP^{\underline{3}}$ l														
Pan	-9	-	-	-	-	1	-6	-	-	-6	-6	2	-	-
Pongo	-	-	-	-	-	-	-8	-	-	-18	+2	2	-	-
H.sapiens(pooled)	-2	-	-	-13	+13	4	-5	-	-	-	-	1	-	-
Romano-British	-1	-	-	-13	+13	3	-	-	-	-	-	-	-	-
Aust.Aborigines	-4	-	-	-	-	1	-5	-	-	-	-	1	-	-

G(vii): Root angulation

	Males						Females						P	
	$\bar{X}$	S.E.	S.D.	min	max	N	$\bar{X}$	S.E.	S.D.	min	max	N	t	F
$2RP^3$ b														
Pan	-6	-	-	-	-	1	-6	-	-	-10	-2	2	-	-
Pongo	-	-	-	-	-	-	-5	-	-	-11	+2	2	-	-
H.sapiens(pooled)	-4	-	-	-13	+6	4	-7	-	-	-	-	1	-	-
Romano-British	-3	-	-	-13	+6	3	-	-	-	-	-	-	-	-
Aust.Aborigines	-8	-	-	-	-	1	-7	-	-	-	-	1	-	-
$1RP^3$														
H.sapiens(pooled)	-2	1.80	6.3	-9	+12	12	0	1.56	5.8	-9	+10	14	NS	NS
Romano-British	-1	2.50	6.6	-8	+12	7	+2	2.42	6.8	-9	+10	8	NS	NS
Aust.Aborigines	-2	2.89	6.5	-9	+5	5	-3	1.01	2.5	-7	0	6	NS	NS
$3RP^4$ l														
Gorilla	-6	0.86	4.1	-17	+3	23	-3	1.17	4.8	-12	+6	17	NS	NS
Pan	-2	-	-	-8	+6	3	-3	-	-	-3	-2	2	-	-
Pongo	-7	0.78	3.1	-11	-2	16	-8	1.72	5.7	-15	+3	11	NS	<.05
$3RP^4$ mb														
Gorilla	-3	1.36	6.5	-15	+14	23	+3	1.43	5.9	-9	+10	17	<.01	NS
Pan	0	-	-	-4	+6	3	-2	-	-	-3	-1	2	-	-
Pongo	-1	1.32	5.3	-8	+8	16	-5	1.50	5.0	-13	+4	11	NS	NS
$3RP^4$ db														
Gorilla	-11	1.47	7.1	-28	-1	23	-11	1.03	4.2	-17	-1	17	NS	<.05
Pan	-10	-	-	-12	-8	3	-5	-	-	-6	-4	2	-	-
Pongo	-7	1.35	5.4	-15	+1	16	-11	1.48	4.9	-22	-6	11	NS	NS

G(vii): Root angulation

	Males						Females						P	
	$\bar{X}$	S.E.	S.D.	min	max	N	$\bar{X}$	S.E.	S.D.	min	max	N	t	F
$2RP^{\underline{4}}$ 1														
Pan	-2	1.36	5.2	-13	+8	17	-5	2.63	7.4	-17	+4	8	NS	NS
Pongo	-5	-	-	-	-	1	-11	-	-	-	-	1	-	-
$2RP^{\underline{4}}$ b														
Pan	-4	1.30	5.3	-13	+8	17	-4	1.61	4.6	-11	+2	8	NS	NS
Pongo	-20	-	-	-	-	1	-10	-	-	-	-	1	-	-
$1RP^{\underline{4}}$														
H.sapiens(pooled)	-3	0.90	3.6	-11	+2	16	-3	1.45	5.8	-10	+12	16	NS	NS
Romano-British	-2	0.98	3.1	-6	+2	10	-1	2.13	6.4	-8	+12	9	NS	<.05
Aust.Aborigines	-5	1.49	3.7	-11	-2	6	-6	1.04	2.8	-10	-3	7	NS	NS
$M^{\underline{1}}$ 1														
Gorilla	-7	0.88	4.2	-17	0	23	-8	1.06	4.4	-14	+2	17	NS	NS
Pan	-7	1.18	5.3	-17	+1	20	-10	1.69	5.6	-19	-3	11	NS	NS
Pongo	-9	0.93	4.0	-15	-1	18	-10	1.16	4.3	-16	-2	14	NS	NS
H.sapiens(pooled)	-6	1.93	7.5	-17	+10	15	-7	1.49	6.0	-19	0	16	NS	NS
Romano-British	-9	1.83	5.8	-17	+1	10	-8	1.98	5.6	-16	-2	8	NS	NS
Aust.Aborigines	0	3.15	7.0	-9	+10	5	-6	2.30	6.5	-19	0	8	NS	NS

G(vii): Root angulation

	$\bar{X}$	S.E.	S.D.	min	max	N	$\bar{X}$	S.E.	S.D.	min	max	N	P t	P F
M^1 mb														
Gorilla	-9	1.85	8.9	-21	+13	23	-4	1.19	4.9	-13	+5	17	<.05	<.05
Pan	0	1.42	6.4	-14	+13	20	-1	1.80	6.0	-16	+6	11	NS	NS
Pongo	-10	1.76	7.5	-24	+2	18	-14	1.79	6.7	-28	-2	14	NS	NS
H.sapiens(pooled)	-4	0.87	3.4	-10	0	15	-5	1.20	4.8	-15	+4	16	NS	NS
Romano-British	-3	1.01	3.2	-8	0	10	-4	1.76	5.0	-12	+4	8	NS	NS
Aust.Aborigines	-7	1.25	2.8	-10	-4	5	-7	1.61	4.6	-15	-2	8	NS	NS
M^1 db														
Gorilla	-18	1.13	5.4	-29	-5	23	-14	1.53	6.3	-25	+1	17	<.05	NS
Pan	-15	1.18	5.3	-25	-4	20	-12	1.77	5.9	-24	-4	11	NS	NS
Pongo	-11	1.78	7.6	-22	+4	18	-15	1.56	5.9	-29	-7	14	NS	NS
H.sapiens(pooled)	-11	1.44	5.6	-24	-4	15	-12	1.34	5.4	-21	-4	16	NS	NS
Romano-British	-12	1.97	6.2	-24	-4	10	-12	2.55	7.2	-21	-4	8	NS	NS
Aust.Aborigines	-11	2.04	4.6	-15	-6	5	-11	1.06	3.0	-15	-7	8	NS	NS
M^2 1														
Gorilla	-5	1.01	4.6	-15	+3	21	-10	1.63	6.3	-20	0	15	<.05	NS
Pan	-8	1.39	6.2	-17	+3	20	-8	1.32	4.2	-16	-2	10	NS	NS
Pongo	-11	1.27	4.8	-21	-3	14	-13	1.37	5.3	-25	-5	15	NS	NS
H.sapiens(pooled)	-9	1.73	6.7	-16	+6	15	-14	1.67	6.0	-23	0	13	NS	NS
Romano-British	-10	1.85	5.6	-16	-2	9	-13	2.46	5.5	-22	-9	5	NS	NS
Aust.Aborigines	-8	3.48	8.5	-16	+6	6	-14	2.37	6.7	-23	0	8	NS	NS

G(vii): Root angulation

	Males						Females						P	
	$\bar{X}$	S.E.	S.D.	min	max	N	$\bar{X}$	S.E.	S.D.	min	max	N	t	F
M^2 mb														
Gorilla	-4	1.13	5.2	-16	+5	21	-6	1.80	7.0	-14	+10	15	NS	NS
Pan	-1	1.27	5.7	-18	+7	20	0	1.02	3.2	-5	+6	10	NS	NS
Pongo	-3	1.67	6.3	-17	+9	14	-7	1.50	5.8	-16	+4	15	NS	NS
H.sapiens(pooled)	-8	1.84	7.1	-17	+11	15	-11	1.35	4.9	-22	0	13	NS	NS
Romano-British	-10	1.37	4.1	-17	-4	9	-7	1.94	4.3	-11	0	5	NS	NS
Aust.Aborigines	-4	3.76	9.2	-15	+11	6	-13	1.52	4.3	-22	-8	8	<.05	NS
M^2 db														
Gorilla	-3	1.66	7.6	-19	+10	21	-6	1.32	5.1	-13	+8	15	NS	NS
Pan	-13	1.83	8.2	-31	+2	20	-8	2.31	7.3	-19	+3	10	NS	NS
Pongo	-5	1.78	6.7	-16	+4	14	-10	0.90	3.5	-17	-5	15	<.05	<.05
H.sapiens(pooled)	-9	1.14	4.4	-18	-1	15	-13	1.31	4.7	-21	-5	13	<.05	NS
Romano-British	-8	1.33	4.0	-16	-1	9	-15	1.83	4.1	-20	-11	5	<.01	NS
Aust.Aborigines	-11	2.05	5.0	-18	-4	6	-11	1.66	4.7	-21	-5	8	NS	NS
M^3 1														
Gorilla	-15	1.79	8.6	-42	-3	23	-20	2.12	7.9	-33	-6	14	NS	NS
Pan	-12	1.67	7.5	-31	0	20	-15	2.49	7.9	-30	-6	10	NS	NS
Pongo	-20	1.77	6.4	-34	-12	13	-20	1.36	4.5	-29	-14	11	NS	NS
H.sapiens(pooled)	-13	3.29	8.1	-23	+1	6	-9	3.23	7.9	-17	+2	6	NS	NS
Romano-British	-6	-	-	-13	+1	2	-13	-	-	-17	-9	2	-	-
Aust.Aborigines	-16	-	-	-23	-11	4	-8	-	-	-17	+2	4	-	-

G(vii): Root angulation

	Males						Females						P	
	$\bar{X}$	S.E.	S.D.	min	max	N	$\bar{X}$	S.E.	S.D.	min	max	N	t	F
M^3 mb														
Gorilla	-6	1.39	6.7	-24	+5	23	-10	1.82	6.8	-17	+5	14	NS	NS
Pan	-1	1.33	5.9	-11	+12	20	-1	2.15	6.8	-8	+11	10	NS	NS
Pongo	-4	2.49	9.0	-16	+11	13	-2	1.84	6.1	-12	+7	11	NS	NS
H.sapiens(pooled)	-12	2.39	5.9	-20	-3	6	-12	3.60	8.8	-25	-2	6	NS	NS
Romano-British	-7	-	-	-11	-3	2	-22	-	-	-25	-18	2	-	-
Aust.Aborigines	-14	-	-	-20	-8	4	-7	-	-	-12	-2	4	-	-
M^3 db														
Gorilla	-11	1.73	8.3	-31	+3	23	-14	1.65	6.2	-26	-3	14	NS	NS
Pan	-17	2.28	10.2	-32	-1	20	-11	2.31	7.3	-21	0	10	NS	NS
Pongo	-19	2.21	8.0	-30	-7	13	-21	2.37	7.9	-34	-9	11	NS	NS
H.sapiens(pooled)	-14	3.52	8.6	-24	-3	6	-16	1.57	3.8	-20	-10	6	NS	NS
Romano-British	-4	-	-	-4	-3	2	-17	-	-	-20	-14	2	-	-
Aust.Aborigines	-19	-	-	-24	-15	4	-15	-	-	-19	-10	4	-	-

G (viii) : Crown mesiodistal diameter

	Males							Females								P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t	F
I_1																	
Gorilla	7.3	0.22	0.9	5.7	8.7	12.3	16	6.6	0.22	0.8	5.1	7.6	11.8	12	90	<.05	NS
Pan	7.2	0.20	0.8	5.6	8.3	11.5	18	7.2	0.23	0.7	5.9	8.0	9.5	9	100	NS	NS
Pongo	9.1	0.23	0.9	7.2	10.9	10.3	16	8.7	0.24	0.9	7.4	10.3	10.7	15	96	NS	NS
H.sapiens(pooled)	4.9	0.13	0.4	4.3	5.8	8.8	11	4.9	0.16	0.6	3.9	5.9	11.5	13	100	NS	NS
Romano-British	4.9	0.11	0.3	4.4	5.3	6.1	8	4.8	0.14	0.4	4.2	5.4	8.9	9	98	NS	NS
Aust.Aborigines	5.1	-	-	4.3	5.8	-	3	5.0	-	-	3.9	5.9	-	4	98	-	-
I_2																	
Gorilla	8.6	0.13	0.6	7.5	9.7	6.6	19	7.8	0.21	0.8	5.8	8.9	10.6	16	91	<.01	NS
Pan	8.0	0.19	0.8	6.5	9.2	10.2	18	8.1	0.24	0.7	6.8	9.0	9 0	9	101	NS	NS
Pongo	8.7	0.21	0.9	7.4	10.1	9.8	16	8.8	0.21	0.8	7.5	10.1	8.8	13	101	NS	NS
H.sapiens(pooled)	5.6	0.07	0.3	5.2	6.0	4.9	14	5.9	0.17	0.7	5.0	7.2	11.3	16	105	NS	<.01
Romano-British	5.6	0.09	0.3	5.2	6.0	5.2	10	5.6	0.13	0.4	5.0	6.2	7.5	10	100	NS	NS
Aust.Aborigines	5.6	-	-	5.2	5.8	-	4	6.4	0.29	0.7	5.1	7.2	11.1	6	114	-	-
C_1																	
Gorilla	14.7	0.32	1.5	12.3	18.7	10.1	22	11.4	0.29	1.1	8.5	13.3	10.0	16	78	<.001	NS
Pan	11.7	0.30	1.4	9.0	14.2	11.7	20	10.2	0.22	0.7	9.5	12.1	7.0	11	87	<.01	<.05
Pongo	13.3	0.33	1.5	10.5	16.0	10.9	19	10.4	0.29	1.1	8.2	11.9	10.8	15	78	<.001	NS
H.sapiens(pooled)	7.1	0.14	0.6	6.1	8.0	7.9	15	6.8	0.16	0.7	5.9	8.2	10.0	17	96	NS	NS
Romano-British	6.8	0.14	0.4	6.1	7.5	6.5	10	6.3	0.10	0.3	5.9	6.9	4.9	10	93	<.01	NS
Aust.Aborigines	7.6	0.16	0.4	7.2	8.0	4.8	5	7.4	0.18	0.5	6.7	8.2	6.4	7	97	NS	NS

G (viii) : Crown mesiodistal diameter

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	P t	P F
$P_{\overline{3}}$																	
Gorilla	15.2	0.20	1.0	13.9	17.5	6.3	23	13.5	0.21	0.9	11.6	15.1	6.4	17	89	<.001	NS
Pan	9.9	0.21	0.9	8.3	12.4	9.5	20	9.4	0.17	0.6	8.5	10.1	6.0	11	95	NS	NS
Pongo	12.8	0.20	0.9	11.3	14.7	6.8	19	11.4	0.19	0.7	10.1	12.6	6.4	15	89	<.001	NS
H.sapiens(pooled)	7.1	0.21	0.9	5.8	8.9	12.0	16	6.8	0.14	0.6	6.0	7.6	8.5	17	96	NS	NS
Romano-British	6.7	0.17	0.5	5.8	7.6	7.9	10	6.5	0.14	0.4	6.0	7.4	6.9	10	97	NS	NS
Aust.Aborigines	7.8	0.36	0.9	6.5	8.9	11.4	6	7.4	0.08	0.2	7.1	7.6	2.8	7	95	NS	<.01
$P_{\overline{4}}$																	
Gorilla	12.0	0.16	0.8	10.7	13.5	6.4	23	11.1	0.16	0.7	10.0	12.3	5.9	17	93	<.001	NS
Pan	8.1	0.12	0.5	6.8	9.0	6.5	20	8.0	0.15	0.5	7.1	8.8	6.2	11	99	NS	NS
Pongo	11.2	0.15	0.7	9.4	12.3	5.9	19	10.3	0.21	0.8	8.8	11.3	7.9	15	92	.001	NS
H.sapiens(pooled)	7.1	0.20	0.8	6.0	8.3	11.0	16	6.9	0.16	0.7	5.9	8.6	10.1	18	97	NS	NS
Romano-British	6.7	0.18	0.6	6.0	7.6	8.3	10	6.5	0.16	0.5	5.9	7.4	7.5	10	97	NS	NS
Aust.Aborigines	7.8	0.26	0.6	6.7	8.3	8.1	6	7.4	0.22	0.6	6.7	8.6	8.3	8	95	NS	NS
$M_{\overline{1}}$																	
Gorilla	16.0	0.17	0.8	14.8	17.8	5.0	23	14.7	0.21	0.9	12.9	15.8	6.0	17	92	<.001	NS
Pan	11.1	0.15	0.7	9.7	12.2	6.0	20	10.9	0.14	0.5	10.2	11.5	4.3	11	98	NS	NS
Pongo	13.5	0.18	0.7	12.4	14.6	5.5	18	12.5	0.12	0.5	11.8	13.3	3.8	15	93	<.001	NS
H.sapiens(pooled)	11.7	0.23	0.9	10.3	13.6	7.7	16	11.1	0.22	0.9	9.3	12.7	8.2	17	95	NS	NS
Romano-British	11.3	0.19	0.6	10.3	12.0	5.2	10	10.6	0.24	0.8	9.3	11.7	7.1	10	94	<.05	NS
Aust.Aborigines	12.5	0.37	0.9	11.6	13.6	7.3	6	11.9	0.23	0.6	11.0	12.7	5.1	7	95	NS	NS

G (viii) : Crown mesiodistal diameter

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t	F
M_2																	
Gorilla	17.7	0.23	1.1	16.3	19.9	6.3	23	16.3	0.25	1.0	14.4	17.6	6.4	17	92	<.001	NS
Pan	11.5	0.16	0.7	10.3	13.1	6.2	19	11.4	0.14	0.5	10.7	12.3	4.0	11	99	NS	NS
Pongo	14.2	0.23	1.0	12.7	16.2	6.8	18	13.2	0.19	0.7	12.0	14.4	5.7	15	93	<.01	NS
H.sapiens(pooled)	11.3	0.31	1.2	9.5	13.8	10.8	16	10.8	0.27	1.1	9.2	12.7	10.6	18	96	NS	NS
Romano-British	10.6	0.19	0.6	9.5	11.6	5.7	10	9.9	0.20	0.6	9.2	10.9	6.5	10	93	<.05	NS
Aust.Aborigines	12.6	0.38	0.9	11.1	13.8	7.4	6	11.8	0.24	0.7	10.7	12.7	5.9	8	94	NS	NS
M_3																	
Gorilla	18.0	0.24	1.1	16.3	20.1	6.4	23	16.4	0.28	1.1	13.6	17.9	6.9	16	91	<.001	NS
Pan	11.0	0.18	0.8	10.0	12.3	7.2	20	10.6	0.19	0.6	9.2	11.6	6.0	11	96	NS	NS
Pongo	14.0	0.24	1.0	12.3	15.6	7.1	17	12.9	0.22	0.8	11.4	14.3	6.5	15	92	<.01	NS
H.sapiens(pooled)	11.1	0.32	1.2	9.5	13.6	11.0	15	10.8	0.30	1.2	8.7	12.3	11.2	16	97	NS	NS
Romano-British	10.4	0.22	0.7	9.5	11.4	6.4	9	10.1	0.37	1.1	8.7	11.6	10,9	9	97	NS	NS
Aust.Aborigines	12.2	0.41	1.0	11.3	13.6	8.2	6	11.7	0.18	0.5	10.9	12.3	4.0	7	96	NS	NS
I^1																	
Gorilla	13.1	0.26	1.1	10.5	15.4	8.4	18	12.1	0.33	1.2	9.6	13.6	9.8	13	92	<.05	NS
Pan	11.3	0.26	1.0	8.9	13.0	8.9	15	10.9	0.24	0.8	9.6	12.1	7.2	11	97	NS	NS
Pongo	14.0	0.28	1.1	12.0	15.9	8.1	17	13.3	0.32	1.1	11.3	15.2	8.4	12	95	NS	NS
H.sapiens(pooled)	8.2	0.19	0.7	7.2	9.3	8.1	12	8.1	0.18	0.7	7.2	9.3	8.2	13	99	NS	NS
Romano-British	8.2	0.18	0.6	7.2	8.9	7.1	10	8.0	0.18	0.6	7.2	8.9	6.9	9	98	NS	NS
Aust.Aborigines	8.4	-	-	7.4	9.3	-	2	8.3	-	-	7.4	9.3	-	4	99	-	-

G (viii) : Crown mesiodistal diameter

	Males							Females								P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t	F
I^2																	
Gorilla	9.0	0.30	1.3	6.4	11.8	14.2	18	8.6	0.18	0.7	7.1	9.6	7.8	14	96	NS	<.05
Pan	8.9	0.29	1.0	6.1	9.9	11.1	12	8.5	0.22	0.7	6.9	9.2	8.1	10	96	NS	NS
Pongo	8.5	0.15	0.6	7.6	9.5	7.4	18	8.3	0.17	0.6	7.3	9.1	6.9	11	98	NS	NS
H.sapiens(pooled)	6.6	0.26	1.0	4.4	8.1	14.6	14	6.7	0.24	0.9	5.6	8.3	12.7	15	102	NS	NS
Romano-British	6.2	0.29	0.9	4.4	7.3	14.1	9	6.1	0.15	0.4	5.6	6.9	6.8	8	98	NS	NS
Aust.Aborigines	7.4	0.25	0.6	6.5	8.1	7.7	5	7.3	0.31	0.8	6.1	8.3	11.1	7	99	NS	NS
P^3																	
Gorilla	12.0	0.16	0.8	10.8	13.8	6.5	23	11.4	0.18	0.8	9.8	12.9	6.7	17	95	<.05	NS
Pan	8.2	0.14	0.6	7.3	9.4	7.5	20	8.4	0.13	0.4	7.6	9.1	5.1	11	102	NS	NS
Pongo	10.1	0.13	0.6	9.1	11.0	5.4	19	9.7	0.15	0.6	8.8	10.6	5.9	15	96	NS	NS
H.sapiens(pooled)	7.1	0.20	0.8	6.0	8.5	11.3	16	6.9	0.18	0.7	5.6	8.2	10.8	17	97	NS	NS
Romano-British	6.6	0.14	0.5	6.0	7.4	6.9	10	6.4	0.13	0.4	5.6	7.0	6.6	10	97	NS	NS
Aust.Aborigines	7.9	0.25	0.6	7.1	8.5	7.8	6	7.5	0.18	0.5	6.9	8.2	6.2	7	95	NS	NS
P^4																	
Gorilla	11.5	0.14	0.7	10.4	13.1	5.9	23	10.9	0.16	0.7	9.6	11.9	6.2	17	95	<.05	NS
Pan	7.5	0.15	0.7	6.5	9.2	8.8	20	7.4	0.14	0.5	6.7	8.4	6.1	10	99	NS	NS
Pongo	9.9	0.11	0.5	8.8	10.6	4.9	19	9.2	0.11	0.4	8.5	10.0	4.5	15	93	<.001	NS
H.sapiens(pooled)	7.0	0.19	0.7	5.9	8.1	10.6	16	6.6	0.15	0.6	5.4	7.7	9.3	17	94	NS	NS
Romano-British	6.5	0.13	0.4	5.9	7.1	6.2	10	6.2	0.13	0.4	5.4	6.8	6.8	10	95	NS	NS
Aust.Aborigines	7.7	0.24	0.6	6.7	8.1	7.7	6	7.1	0.13	0.3	6.7	7.7	4.8	7	92	NS	NS

G (viii) : Crown mesiodistal diameter

	Males							Females								P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t	F
M^1																	
Gorilla	15.0	0.18	0.8	13.2	16.8	5.6	23	14.0	0.24	0.9	12.2	15.1	6.8	16	93	.001	NS
Pan	10.5	0.17	0.8	8.5	12.0	7.3	19	10.3	0.19	0.6	9.4	11.2	6.0	11	98	NS	NS
Pongo	12.5	0.20	0.8	10.4	13.9	6.6	18	11.7	0.16	0.6	10.9	13.2	5.3	15	94	<.01	NS
H.sapiens(pooled)	10.8	0.24	0.9	9.5	12.7	8.6	15	10.3	0.21	0.8	9.0	11.8	8.1	16	95	NS	NS
Romano-British	10.3	0.14	0.4	9.5	11.1	4.2	10	9.8	0.24	0.7	9.0	10.8	7.1	8	95	NS	NS
Aust.Aborigines	11.9	0.32	0.7	11.3	12.7	5.9	5	10.9	0.20	0.6	10.2	11.8	5.1	8	92	<.05	NS
M^2																	
Gorilla	16.5	0.25	1.2	14.6	18.7	7.2	23	15.1	0.21	0.9	13.6	16.3	5.8	17	92	<.001	NS
Pan	10.6	0.18	0.8	9.0	12.3	7.4	19	10.4	0.15	0.5	9.4	11.0	4.9	11	98	NS	NS
Pongo	12.6	0.26	1.1	10.2	14.3	8.9	19	11.5	0.19	0.7	10.6	12.6	6.4	15	91	<.01	NS
H.sapiens(pooled)	10.2	0.33	1.3	8.0	12.4	13.0	16	9.5	0.29	1.1	7.9	11.3	11.6	15	93	NS	NS
Romano-British	9.3	0.22	0.7	8.0	10.5	7.6	10	8.5	0.21	0.6	7.9	9.5	6.6	7	91	<.05	NS
Aust.Aborigines	11.6	0.31	0.8	10.6	12.4	6.5	6	10.4	0.21	0.6	9.2	11.3	5.8	8	90	<.01	NS
M^3																	
Gorilla	15.5	0.22	1.0	13.2	17.7	6.7	23	14.0	0.29	1.2	11.9	15.8	8.5	17	90	<.001	NS
Pan	9.8	0.19	0.8	8.6	12.3	8.3	19	9.3	0.21	0.7	7.9	10.4	7.3	11	95	NS	NS
Pongo	11.9	0.30	1.3	8.8	13.2	10.9	19	10.8	0.18	0.7	9.7	11.9	6.3	15	91	<.01	<.05
H.sapiens(pooled)	8.6	0.34	1.3	5.8	10.3	14.9	14	8.9	0.33	1.3	5.9	11.1	14.3	15	104	NS	NS
Romano-British	8.0	0.31	1.0	5.8	8.9	12.3	10	8.0	0.44	1.2	5.9	9.4	14.6	7	100	NS	NS
Aust.Aborigines	10.1	-	-	9.5	10.3	-	4	9.6	0.30	0.9	8.5	11.1	9.0	8	95	-	-

G (ix) : Crown buccolingual diameter

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t	F
I_1																	
Gorilla	9.5	0.20	0.8	8.3	10.7	8.1	15	8.4	0.19	0.7	7.1	9.3	7.8	12	88	.001	NS
Pan	8.7	0.16	0.7	7.2	10.1	7.9	18	8.6	0.16	0.5	7.9	9.4	5.6	9	99	NS	NS
Pongo	10.0	0.20	0.8	8.6	11.2	7.9	16	9.0	0.15	0.6	7.8	10.1	6.5	15	90	.001	NS
H.sapiens(pooled)	5.9	0.13	0.4	5.1	6.7	7.0	11	5.9	0.14	0.5	5.0	6.6	8.6	13	100	NS	NS
Romano-British	5.8	0.13	0.4	5.1	6.4	6.3	8	5.7	0.17	0.5	5.0	6.4	8.7	9	98	NS	NS
Aust.Aborigines	6.0	-	-	5.6	6.7	-	3	6.3	-	-	6.1	6.6	-	4	105	-	-
I_2																	
Gorilla	10.5	0.19	0.9	9.5	12.8	8.1	20	9.0	0.20	0.8	7.5	10.1	8.8	16	96	<.001	NS
Pan	9.1	0.19	0.8	7.7	10.9	8.7	18	8.8	0.21	0.6	8.2	10.2	7.3	9	97	NS	NS
Pongo	10.3	0.19	0.8	8.4	12.0	7.4	17	9.4	0.16	0.6	8.4	11.0	6.8	15	91	.001	NS
H.sapiens(pooled)	6.2	0.14	0.5	5.3	7.1	8.4	14	6.2	0.12	0.5	5.4	7.0	7.9	16	100	NS	NS
Romano-British	6.0	0.14	0.4	5.3	6.8	7.1	10	6.0	0.12	0.4	5.4	6.5	6.2	10	100	NS	NS
Aust.Aborigines	6.8	-	-	6.6	7.1	-	4	6.4	0.23	0.6	5.6	7.0	8.7	6	94	-	-
C_1																	
Gorilla	17.1	0.41	1.9	15.0	23.1	11.2	22	12.1	0.19	0.8	10.7	13.6	6.3	16	71	<.001	.001
Pan	13.2	0.37	1.7	9.5	16.3	12.6	20	10.6	0.35	1.2	8.9	13.6	11.0	11	80	<.001	NS
Pongo	14.6	0.35	1.5	11.3	17.1	10.5	19	11.6	0.33	1.3	9.5	13.5	10.9	15	80	<.001	NS
H.sapiens(pooled)	8.0	0.20	0.8	7.0	9.7	9.4	14	7.5	0.18	0.7	6.3	8.9	9.8	16	94	NS	NS
Romano-British	7.7	0.16	0.5	7.0	8.4	6.5	10	7.0	0.14	0.4	6.3	7.5	6.1	9	91	<.01	NS
Aust.Aborigines	8.8	-	-	7.9	9.7	-	4	8.2	0.19	0.5	7.4	8.9	6.3	7	93	-	-

G (ix) : Crown buccolingual diameter

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t F
P_3																
Gorilla	13.7	0.30	1.4	11.9	18.2	10.5	23	12.1	0.32	1.3	10.0	14.8	10.7	17	88	.001 NS
Pan	9.1	0.22	1.0	7.2	10.7	10.8	20	9.0	0.22	0.7	7.8	10.5	8.2	11	99	NS NS
Pongo	12.4	0.31	1.4	10.0	15.8	10.9	19	10.7	0.20	0.8	9.5	11.8	7.1	15	86	<.001 <.05
H.sapiens(pooled)	8.1	0.20	0.8	7.0	9.6	9.9	16	7.8	0.19	0.8	6.7	9.0	9.9	17	96	NS NS
Romano-British	7.6	0.16	0.5	7.0	8.4	6.8	10	7.2	0.13	0.4	6.7	7.9	5.8	10	95	NS NS
Aust.Aborigines	8.8	0.24	0.6	8.0	9.6	6.6	6	8.5	0.14	0.4	8.0	9.0	4.2	7	97	NS NS
P_4																
Gorilla	13.2	0.21	1.0	11.6	15.4	7.5	23	12.1	0.23	1.0	10.0	13.6	8.0	17	92	<.01 NS
Pan	8.8	0.12	0.5	7.9	9.6	6.1	20	8.8	0.14	0.5	8.1	9.5	5.2	11	100	NS NS
Pongo	11.9	0.17	0.8	10.5	13.0	6.3	19	10.8	0.15	0.6	9.6	11.8	5.5	15	91	<.001 NS
H.sapiens(pooled)	8.5	0.17	0.7	7.5	9.4	7.7	16	8.0	0.18	0.8	6.6	9.2	9.5	18	94	<.05 NS
Romano-British	8.2	0.16	0.5	7.5	8.9	6.2	10	7.6	0.22	0.7	6.6	8.9	9.1	10	93	NS NS
Aust.Aborigines	9.2	0.09	0.2	8.8	9.4	2.4	6	8.5	0.20	0.6	7.8	9.2	6.6	8	92	<.05 NS
M_1																
Gorilla	13.7	0.19	0.9	12.6	15.7	6.5	23	12.8	0.23	0.9	11.1	14.5	7.3	17	93	<.01 NS
Pan	10.0	0.13	0.6	8.7	10.8	5.8	20	9.6	0.14	0.5	8.9	10.3	5.0	11	96	NS NS
Pongo	12.4	0.15	0.6	11.2	13.5	5.1	18	11.5	0.12	0.5	10.6	12.4	4.0	15	93	<.001 NS
H.sapiens(pooled)	11.2	0.22	0.9	9.7	12.6	7.8	16	10.7	0.21	0.9	9.5	12.4	8.0	17	96	NS NS
Romano-British	10.6	0.13	0.4	9.7	11.1	3.9	10	10.1	0.15	0.5	9.5	10.9	4.8	10	95	<.05 NS
Aust.Aborigines	12.1	0.17	0.4	11.6	12.6	3.5	6	11.5	0.19	0.5	11.0	12.4	4.3	7	95	<.05 NS

G (ix) : Crown buccolingual diameter

	Males							Females								P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t	F
M_2																	
Gorilla	15.5	0.24	1.1	13.9	18.0	7.3	23	14.4	0.26	1.1	12.4	16.3	7.3	17	93	<.01	NS
Pan	10.8	0.15	0.7	9.5	12.3	6.2	19	10.4	0.20	0.7	9.5	11.4	6.5	11	96	NS	NS
Pongo	13.2	0.21	0.9	11.7	14.6	6.6	18	11.9	0.18	0.7	10.2	13.1	5.7	15	90	<.001	NS
H.sapiens(pooled)	10.7	0.25	1.0	9.2	12.3	9.2	16	10.3	0.28	1.2	8.2	12.5	11.7	18	96	NS	NS
Romano-British	10.0	0.17	0.5	9.2	10.9	5.3	10	9.4	0.24	0.8	8.2	10.6	8.1	10	94	<.05	NS
Aust.Aborigines	11.8	0.17	0.4	11.2	12.3	3.6	6	11.3	0.19	0.5	11.0	12.5	4.8	8	96	NS	NS
M_3																	
Gorilla	15.0	0.19	0.9	13.9	17.3	6.2	23	13.8	0.25	1.0	11.9	15.9	7.2	16	92	<.001	NS
Pan	10.3	0.12	0.5	9.2	11.3	5.2	20	10.0	0.25	0.8	8.4	11.5	8.3	11	97	NS	NS
Pongo	12.5	0.22	0.9	11.0	14.2	7.3	17	11.4	0.18	0.7	9.9	12.7	6.1	15	91	.001	NS
H.sapiens(pooled)	10.5	0.28	1.1	9.0	12.7	10.4	15	10.1	0.29	1.2	8.1	12.2	11.5	16	96	NS	NS
Romano-British	9.8	0.21	0.6	9.0	10.8	6.5	9	9.4	0.30	0.9	8.1	10.8	9.5	9	96	NS	NS
Aust.Aborigines	11.5	0.35	0.9	10.3	12.7	7.4	6	11.1	0.21	0.6	10.7	12.2	5.0	7	97	NS	NS
I_1																	
Gorilla	10.9	0.24	1.0	9.8	12.8	9.0	17	10.0	0.17	0.6	8.5	10.8	6.0	12	92	<.05	NS
Pan	9.1	0.19	0.7	7.9	10.2	8.0	15	8.9	0.19	0.6	8.1	9.8	7.1	11	98	NS	NS
Pongo	12.4	0.23	1.0	10.7	14.2	7.7	17	11.1	0.27	1.0	9.0	12.8	8.5	12	90	.001	NS
H.sapiens(pooled)	7.2	0.14	0.5	6.4	8.2	6.9	12	7.1	0.21	0.8	6.2	8.4	10.7	13	99	NS	NS
Romano-British	7.1	0.13	0.4	6.4	7.6	5.7	10	6.7	0.13	0.4	6.2	7.3	5.7	9	94	<.05	NS
Aust.Aborigines	7.9	-	-	7.5	8.2	-	2	8.1	-	-	7.6	8.4	-	4	103	-	-

G (ix) : Crown buccolingual diameter

	Males							Females								P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t	F
I^2																	
Gorilla	10.1	0.33	1.4	8.9	13.5	13.3	17	8.9	0.24	0.9	7.8	11.2	9.9	14	88	<.01	NS
Pan	8.4	0.17	0.6	7.3	9.5	7.0	12	8.4	0.18	0.6	7.7	9.6	6.6	10	100	NS	NS
Pongo	8.9	0.17	0.7	7.4	10.7	8.3	18	8.2	0.20	0.7	6.8	9.3	8.2	11	92	.01	NS
H.sapiens(pooled)	6.4	0.20	0.8	4.8	7.7	11.7	14	6.3	0.17	0.6	5.5	7.5	10.1	15	98	NS	NS
Romano-British	6.1	0.22	0.7	4.8	7.1	10.6	9	5.9	0.10	0.3	5.5	6.3	4.8	8	97	NS	<.05
Aust.Aborigines	7.1	0.22	0.5	6.5	7.7	7.0	5	6.9	0.19	0.5	6.1	7.5	7.2	7	97	NS	NS
p^3																	
Gorilla	16.1	0.22	1.1	14.7	18.2	6.7	23	14.8	0.26	1.1	12.4	16.7	7.2	17	92	.001	NS
Pan	10.4	0.19	0.8	8.2	11.9	8.1	20	10.2	0.14	0.5	9.5	11.1	4.6	11	98	NS	NS
Pongo	12.9	0.15	0.7	12.0	14.3	5.2	19	11.8	0.15	0.6	10.9	12.9	4.8	15	92	<.001	NS
H.sapiens(pooled)	9.7	0.28	1.1	7.1	11.7	11.7	16	9.1	0.25	1.0	7.7	11.2	11.4	17	94	NS	NS
Romano-British	9.0	0.28	0.9	7.1	10.1	9.9	10	8.4	0.19	0.6	7.7	9.5	7.3	10	93	NS	NS
Aust.Aborigines	10.8	0.20	0.5	10.3	11.7	4.6	6	10.2	0.20	0.5	9.5	11.2	5.1	7	94	NS	NS
p_4																	
Gorilla	15.5	0.23	1.1	13.0	18.1	7.1	23	14.3	0.22	0.9	12.3	15.8	6.4	17	92	.001	NS
Pan	10.4	0.16	0.7	8.7	11.7	7.1	20	10.2	0.14	0.5	9.6	11.0	4.5	10	98	NS	NS
Pongo	13.2	0.16	0.7	11.8	14.2	5.2	19	12.2	0.15	0.6	11.0	13.2	4.7	15	92	<.001	NS
H.sapiens(pooled)	9.7	0.25	1.0	7.9	11.6	10.4	16	9.2	0.20	0.8	8.0	10.8	9.1	17	95	NS	NS
Romano-British	9.1	0.23	0.7	7.9	10.2	7.9	10	8.8	0.23	0.7	8.0	10.2	8.3	10	97	NS	NS
Aust.Aborigines	10.6	0.29	0.7	9.5	11.6	6.8	6	9.9	0.19	0.5	9.4	10.8	5.0	7	93	NS	NS

G (ix) : Crown buccolingual diameter

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t F
M^1																
Gorilla	15.7	0.20	0.9	14.5	17.6	5.9	22	14.8	0.19	0.8	13.5	16.4	5.1	16	94	<.01 NS
Pan	11.5	0.13	0.6	10.4	12.5	4.8	19	11.5	0.13	0.4	10.9	12.4	3.9	11	100	NS NS
Pongo	13.7	0.16	0.7	12.6	14.9	4.8	18	12.7	0.13	0.5	11.8	13.7	4.1	15	93	<.001 NS
H.sapiens(pooled)	11.9	0.23	0.9	10.2	13.7	7.5	15	11.8	0.27	1.1	9.9	13.6	9.0	16	99	NS NS
Romano-British	11.4	0.16	0.5	10.2	11.9	4.3	10	11.0	0.25	0.7	9.9	11.9	6.5	8	97	NS NS
Aust.Aborigines	12.9	0.25	0.6	12.4	13.7	4.3	5	12.7	0.21	0.6	12.0	13.6	4.7	8	99	NS NS
M^2																
Gorilla	16.9	0.23	1.1	15.0	19.4	6.7	23	15.7	0.23	1.0	13.8	17.5	6.1	17	93	<.01 NS
Pan	11.9	0.18	0.8	10.6	13.8	6.4	18	11.8	0.18	0.6	10.9	13.1	5.1	11	99	NS NS
Pongo	14.4	0.21	0.9	13.0	16.4	6.3	19	13.1	0.15	0.6	12.2	14.2	4.3	15	91	<.001 NS
H.sapiens(pooled)	12.2	0.34	1.4	10.2	15.1	11.1	16	11.8	0.36	1.4	9.6	14.1	11.8	15	97	NS NS
Romano-British	11.4	0.18	0.6	10.2	12.1	4.9	10	10.5	0.22	0.6	9.6	11.5	5.6	7	92	<.01 NS
Aust.Aborigines	13.7	0.44	1.1	12.1	15.1	7.9	6	13.0	0.25	0.7	12.2	14.1	5.4	8	95	NS NS
M^3																
Gorilla	16.1	0.22	1.1	14.5	18.7	6.6	23	14.6	0.28	1.1	12.2	16.1	7.8	17	91	<.001 NS
Pan	11.4	0.14	0.6	10.4	12.8	5.5	20	11.2	0.20	0.7	9.8	12.0	5.8	11	98	NS NS
Pongo	13.8	0.17	0.7	12.7	15.1	5.3	19	12.8	0.16	0.6	11.8	14.2	5.0	15	93	<.001 NS
H.sapiens(pooled)	11.0	0.50	1.9	6.6	13.7	16.9	14	11.3	0.45	1.7	8.4	14.4	15.4	15	103	NS NS
Romano-British	10.2	0.47	1.5	6.6	12.2	14.5	10	9.9	0.44	1.2	8.4	12.0	11.6	7	97	NS NS
Aust.Aborigines	13.1	-	-	12.2	13.7	-	4	12.4	0.44	1.2	11.2	14.4	9.9	8	95	- -

G (x) : Jaw dimensions

	Males							Females								P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t	F
Palatal length																	
Gorilla	102	2.00	9.4	88	123	9.2	22	82	1.31	5.3	73	91	6.4	16	80	<.001	<.05
Pan	73	1.07	4.8	66	83	6.6	20	68	1.48	4.9	60	77	7.2	11	93	<.05	NS
Pongo	81	1.15	5.0	71	88	6.2	19	71	1.02	4.0	64	76	5.6	15	88	<.001	NS
H.sapiens(pooled)	52	1.61	6.4	41	65	12.5	16	49	1.32	5.6	39	59	11.4	18	94	NS	NS
Romano-British	48	1.22	3.9	41	54	8.1	10	45	1.04	3.3	39	50	7.3	10	94	NS	NS
Aust.Aborigines	58	1.97	4.8	51	65	8.4	6	54	1.16	3.3	50	59	6.1	8	93	NS	NS
Palatal breadth																	
Gorilla	75	0.87	4.2	67	82	5.6	23	68	0.93	3.7	63	78	5.5	16	91	<.001	NS
Pan	61	0.63	2.7	57	67	4.5	19	60	0.87	2.9	56	66	4.8	11	98	NS	NS
Pongo	72	0.87	3.8	66	78	5.3	19	64	0.54	2.1	60	68	3.3	15	89	<.001	<.05
H.sapiens(pooled)	66	1.15	4.6	56	73	7.0	16	61	1.22	5.2	53	72	8.5	18	92	.01	NS
Romano-British	64	1.47	4.7	56	73	7.3	10	58	1.10	3.5	53	63	6.0	10	91	<.01	NS
Aust.Aborigines	68	1.37	3.3	64	73	4.9	6	65	1.56	4.4	60	72	6.8	8	96	NS	NS
Mandib.length																	
Gorilla	118	1.33	6.3	108	136	5.3	22	101	1.27	5.2	91	110	5.2	17	86	<.001	NS
Pan	87	1.07	4.8	77	95	5.5	20	81	1.14	3.8	75	87	4.7	11	93	<.01	NS
Pongo	103	1.21	5.3	95	113	5.1	19	91	1.30	5.1	79	100	5.5	15	88	<.001	NS
H.sapiens(pooled)	66	1.56	6.2	56	77	9.4	16	64	1.50	6.4	50	77	10.0	18	97	NS	NS
Romano-British	63	1.17	3.7	56	69	5.9	10	60	1.42	4.5	50	65	7.5	10	95	NS	NS
Aust.Aborigines	73	1.41	3.4	67	77	4.7	6	69	1.64	4.7	61	77	6.8	8	95	NS	NS

G (x) : Jaw dimensions

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t	F
Mandib.depth C_1																	
Gorilla	51.9	0.88	4.2	44.1	60.4	8.2	23	43.1	0.79	3.3	36.4	48.9	7.6	17	83	<.001	NS
Pan	35.4	0.75	3.4	27.8	41.1	9.5	20	32.1	0.81	2.7	28.0	37.2	8.4	11	91	<.01	NS
Pongo	49.5	1.18	5.1	39.8	60.4	10.4	19	42.0	1.15	4.3	33.1	48.2	10.3	14	85	<.001	NS
H.sapiens(pooled)	32.9	0.88	3.5	27.9	39.6	10.7	16	28.9	0.68	2.9	21.8	32.7	10.0	18	88	.001	NS
Romano-British	32.4	1.17	3.7	27.9	39.6	11.4	10	28.7	0.80	2.5	25.1	32.5	8.8	10	89	<.05	NS
Aust.Aborigines	33.7	1.37	3.4	29.3	37.8	10.0	6	29.1	1.22	3.4	21.8	32.7	11.8	8	86	<.05	NS
Mandib.depth M_1																	
Gorilla	41.5	0.77	3.7	33.2	48.4	8.9	23	34.4	0.71	2.9	27.4	40.9	8.5	17	83	<.001	NS
Pan	29.5	0.65	2.9	24.7	34.8	9.8	20	27.0	0.63	2.1	23.5	30.2	7.7	11	92	<.05	NS
Pongo	40.3	1.15	5.0	30.2	48.5	12.4	19	34.2	0.89	3.4	27.3	39.9	10.1	15	85	<.001	NS
H.sapiens(pooled)	30.4	0.79	3.2	24.9	35.6	10.4	16	26.8	0.48	2.0	22.2	29.2	7.6	18	88	<.001	NS
Romano-British	30.4	0.92	2.9	27.1	35.6	9.6	10	26.9	0.62	2.0	23.9	29.2	7.3	10	89	<.01	NS
Aust.Aborigines	30.3	1.57	3.8	24.9	35.2	12.7	6	26.7	0.79	2.2	22.2	29.1	8.4	8	88	<.05	NS
Mandib.depth M_2																	
Gorilla	38.8	0.68	3.3	33.1	46.5	8.4	23	32.6	0.62	2.5	26.6	36.8	7.8	17	84	<.001	NS
Pan	27.7	0.65	2.9	22.9	32.6	10.5	20	25.9	0.60	2.0	22.5	28.9	7.7	11	94	NS	NS
Pongo	37.6	1.05	4.6	29.0	46.3	12.1	19	32.8	0.72	2.8	27.7	38.6	8.5	15	87	.001	NS
H.sapiens(pooled)	27.5	0.68	2.7	22.6	32.3	9.9	16	25.1	0.44	1.9	21.8	28.3	7.5	18	91	<.01	NS
Romano-British	27.6	0.79	2.5	23.9	32.3	9.0	10	25.3	0.66	2.1	22.1	28.3	8.3	10	92	<.05	NS
Aust.Aborigines	27.2	1.35	3.3	22.6	31.0	12.2	6	25.0	0.61	1.7	21.8	27.5	6.9	8	92	NS	NS

G (x) : Jaw dimensions

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t	F
Mandib.depth $M_{\overline{3}}$																	
Gorilla	41.2	0.69	3.3	35.9	50.2	8.0	23	35.9	0.83	3.4	29.5	41.8	9.6	17	97	<.001	NS
Pan	28.1	0.62	2.8	24.5	31.8	9.8	20	27.1	0.63	2.1	24.2	30.0	7.7	11	96	NS	NS
Pongo	38.7	1.09	4.6	31.6	50.4	11.9	18	34.2	0.66	2.6	30.3	39.9	7.5	15	88	<.01	<.05
H.sapiens(pooled)	28.3	0.53	2.1	24.7	31.5	7.3	15	25.0	0.54	2.2	21.0	29.4	8.9	17	88	<.001	NS
Romano-British	29.0	0.65	2.0	25.7	31.5	6.7	9	25.7	0.79	2.4	21.7	29.4	9.2	9	89	<.01	NS
Aust.Aborigines	27.1	0.71	1.7	24.7	29.4	6.4	6	24.2	0.68	1.9	21.0	27.1	7.9	8	89	<.05	NS

Appendix H : Statistical summaries for the indices computed from root, crown and jaw dimensions in the males and females of the pongids and Homo sapiens

H (i) : Location of bifurcation

H (ii) : Root robusticity

H (iii) : Height of bifurcation index

H (iv) : Root divergence

H(1): Location of bifurcation index

	Males							Females								P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t	F
$2RP_3$																	
Gorilla	51.2	1.05	5.0	39.0	63.2	9.8	23	51.1	0.91	3.8	43.7	58.3	7.4	17	100	NS	NS
Pan	52.3	0.78	3.1	46.7	57.9	6.0	16	53.7	2.02	5.0	47.5	61.9	9.2	6	103	NS	NS
Pongo	51.1	0.92	4.0	43.4	57.4	7.9	19	53.5	0.80	3.0	50.0	58.3	5.6	14	105	NS	NS
H.sapiens(pooled)	50.8	-	-	-	-	--	1	-	-	-	-	-	-	-	-	-	-
$2RP_4$																	
Gorilla	46.4	0.70	3.3	41.7	56.2	7.1	22	46.7	0.66	2.7	42.1	50.5	5.8	17	101	NS	NS
Pan	49.3	0.99	4.4	43.8	57.4	9.0	20	47.8	1.17	3.9	42.9	55.8	8.1	11	97	NS	NS
Pongo	47.7	0.78	3.4	42.6	55.2	7.1	19	47.6	0.82	3.2	42.7	54.4	6.7	15	100	NS	NS
M_1																	
Gorilla	46.2	0.59	2.8	39.5	50.7	6.1	23	47.6	0.60	2.5	43.0	53.0	5.2	17	103	NS	NS
Pan	50.5	0.64	2.9	44.2	54.0	5.7	20	50.4	1.29	4.3	42.9	59.6	8.5	11	100	NS	NS
Pongo	49.1	0.71	3.1	43.7	56.2	6.3	19	49.3	0.66	2.6	42.7	54.5	5.2	15	100	NS	NS
H.sapiens(pooled)	52.0	0.84	3.4	44.4	56.4	6.5	16	51.1	0.76	3.2	44.8	57.1	6.2	17	98	NS	NS
M_2																	
Gorilla	47.3	0.63	3.0	40.7	53.2	6.4	23	48.9	0.85	3.5	41.0	55.2	7.1	17	103	NS	NS
Pan	50.5	0.75	3.3	46.2	59.8	6.6	20	48.3	0.88	2.9	44.0	53.0	6.1	11	96	NS	NS
Pongo	48.2	0.46	2.0	45.2	52.6	4.1	19	50.6	1.10	4.3	45.0	58.7	8.4	15	105	NS	$<.01$
H.sapiens(pooled)	50.3	0.90	3.6	45.0	58.3	7.2	16	50.6	0.94	3.9	41.2	56.7	7.7	17	101	NS	NS

H(i): Location of bifurcation index

	Males							Females								P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t	F
M_3																	
Gorilla	48.6	0.88	4.2	41.1	59.7	8.7	23	48.3	0.76	3.1	43.0	53.3	6.3	16	99	NS	NS
Pan	51.3	1.09	4.8	36.8	57.8	9.4	20	51.7	1.63	5.4	41.6	58.3	10.5	11	101	NS	NS
Pongo	51.8	0.92	4.0	44.2	58.9	7.7	19	50.8	1.16	4.5	36.4	56.4	8.9	15	98	NS	NS
H.sapiens(pooled)	52.2	1.12	4.2	47.6	61.2	8.0	14	51.7	1.53	5.7	44.0	63.8	11.0	14	99	NS	NS

H(11): Root robusticity index

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t F
C_{-1}																
Gorilla	37.2	1.64	6.8	29.7	59.6	18.2	17	28.1	1.05	3.8	24.0	35.0	13.5	13	76	<.001 <.05
Pan	30.5	0.92	3.7	25.2	41.3	12.1	16	30.0	1.32	4.4	20.5	34.9	14.6	11	98	NS NS
Pongo	26.6	1.14	2.8	22.6	30.1	10.5	6	25.2	1.87	5.6	18.6	33.2	22.2	9	95	NS NS
H.sapiens(pooled)	29.8	1.99	7.4	17.7	42.9	24.9	14	32.0	1.07	4.4	24.7	40.5	13.8	17	107	NS NS
$2RP_{-3}$ m																
Gorilla	25.8	0.72	3.5	18.4	33.8	13.5	23	25.2	0.75	3.0	20.0	29.7	11.9	16	98	NS NS
Pan	21.4	0.79	3.2	15.8	26.4	14.7	16	22.7	1.13	2.8	18.8	26.3	12.2	6	106	NS NS
Pongo	19.8	0.87	3.6	13.8	25.9	18.1	17	19.9	1.01	3.7	13.7	25.7	18.4	13	101	NS NS
H.sapiens(pooled)	11.0	-	-	-	-	-	1	-	-	-	-	-	-	-	-	- -
$2RP_{-3}$ d																
Gorilla	24.7	0.88	4.2	17.5	33.0	17.1	23	24.5	0.67	2.7	20.7	30.9	11.0	16	99	NS NS
Pan	21.2	0.81	3.2	16.8	29.5	15.2	16	20.1	1.08	2.7	16.7	23.7	13.2	6	95	NS NS
Pongo	19.7	0.76	3.2	14.2	26.0	16.0	17	19.6	0.95	3.4	13.0	23.9	17.4	13	100	NS NS
H.sapiens(pooled)	17.1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	- -
$1RP_{-3}$																
Pan	31.7	-	-	27.2	37.4	-	4	37.7	3.09	6.9	29.4	46.9	18.3	5	119	- -
Pongo	-	-	-	-	-	-	-	24.0	-	-	-	-	-	1	-	- -
H.sapiens(pooled)	22.1	0.74	2.8	16.4	27.4	12.5	14	22.7	1.11	4.6	17.7	34.1	20.2	17	103	NS NS

H(11): Root robusticity index

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t F
$2RP_{\bar{4}}$ m																
Gorilla	18.8	0.46	2.1	15.2	22.7	11.4	22	20.0	0.49	1.9	17.4	24.2	9.5	15	106	NS NS
Pan	18.4	0.63	2.8	14.4	25.2	15.4	20	20.7	0.89	2.8	17.7	26.1	13.6	10	113	<.05 NS
Pongo	16.7	0.75	3.1	12.2	21.7	18.5	17	17.6	0.81	3.1	11.1	23.2	17.8	15	105	NS NS
$2RP_{\bar{4}}$ d																
Gorilla	22.9	0.52	2.5	19.2	28.3	10.7	22	24.3	0.56	2.3	21.0	28.0	9.3	16	106	NS NS
Pan	21.6	0.76	3.4	14.3	28.9	15.8	20	23.5	1.27	4.0	17.1	31.7	17.1	10	109	NS NS
Pongo	19.6	0.82	3.4	14.6	27.4	17.2	17	19.9	0.92	3.6	13.5	29.0	17.9	15	102	NS NS
$1RP_{\bar{4}}$																
H.sapiens(pooled)	22.7	0.86	3.3	16.9	28.1	14.6	15	24.2	0.88	3.7	17.2	29.5	15.5	18	107	NS NS
$M_{\bar{1}}$ m																
Gorilla	25.3	1.09	5.2	16.3	37.9	20.7	23	26.0	1.11	4.6	19.6	35.0	17.7	17	103	NS NS
Pan	29.0	0.88	4.0	24.2	35.8	13.6	20	28.9	1.38	4.6	22.4	35.5	15.8	11	100	NS NS
Pongo	19.2	0.81	3.5	15.0	27.2	18.4	19	19.0	0.66	2.5	14.8	22.5	13.4	15	99	NS NS
H.sapiens(pooled)	26.4	1.07	4.3	20.0	36.3	16.2	16	25.7	1.02	4.2	20.2	35.3	16.3	17	97	NS NS
$M_{\bar{1}}$ d																
Gorilla	30.6	0.93	4.5	22.3	40.4	14.6	23	28.4	0.88	3.6	21.3	36.0	12.8	17	93	NS NS
Pan	27.7	0.55	2.5	23.2	33.1	8.8	20	26.5	0.93	3.1	22.5	32.8	11.6	11	96	NS NS
Pongo	21.0	0.99	4.3	13.6	28.8	20.5	19	20.4	0.91	3.5	15.8	26.2	17.2	15	97	NS NS
H.sapiens(pooled)	25.2	0.70	2.8	20.6	30.3	11.1	16	24.3	0.68	2.8	19.4	28.5	11.6	17	96	NS NS

H(11): Root robusticity index

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t F
M_2 m																
Gorilla	25.6	0.92	4.4	18.1	35.5	17.2	23	26.6	0.93	3.8	20.8	37.7	14.4	17	104	NS NS
Pan	29.0	0.88	4.0	24.2	35.8	13.6	20	28.9	0.84	2.8	24.3	33.6	9.7	11	100	NS NS
Pongo	20.6	1.02	4.2	15.6	30.8	20.5	17	22.0	1.22	4.6	13.9	32.1	20.8	14	107	NS NS
H.sapiens(pooled)	23.6	0.98	3.9	17.3	32.3	16.6	16	23.2	0.56	2.3	18.0	27.8	10.0	17	98	NS <.05
M_2 d																
Gorilla	33.7	1.06	5.1	22.8	45.3	15.1	23	32.1	0.68	2.7	26.7	35.8	8.5	16	95	NS <.05
Pan	30.3	0.92	4.1	24.6	37.9	13.5	20	30.9	1.38	4.6	25.2	38.2	14.8	11	102	NS NS
Pongo	23.9	0.99	3.8	18.0	31.0	16.1	15	25.5	1.51	5.4	15.9	35.6	21.3	13	107	NS NS
H.sapiens(pooled)	26.2	0.93	3.7	17.5	32.1	14.2	16	27.5	0.95	3.9	22.4	34.6	14.3	17	105	NS NS
M_3 m																
Gorilla	29.1	1.01	4.7	20.1	40.2	16.3	22	31.2	1.27	4.9	24.1	45.0	15.8	15	107	NS NS
Pan	36.8	1.37	6.1	27.5	50.0	16.7	20	37.3	1.48	4.9	30.6	43.4	13.1	11	101	NS NS
Pongo	23.8	1.40	5.1	18.0	36.5	21.3	13	25.7	0.90	2.4	23.6	30.8	9.2	7	108	NS NS
H.sapiens(pooled)	28.7	1.15	4.1	21.6	35.7	14.4	13	28.2	0.95	3.6	22.2	33.1	12.6	14	98	NS NS
M_3 d																
Gorilla	40.5	1.56	6.8	30.5	54.8	16.7	19	44.5	2.22	8.1	32.0	57.0	18.0	13	110	NS NS
Pan	40.9	1.67	7.3	28.7	52.6	17.8	19	39.1	1.82	5.8	32.4	51.8	14.7	10	96	NS NS
Pongo	27.3	2.22	7.7	15.9	38.3	28.2	12	35.3	3.59	9.5	28.4	56.1	26.9	7	129	NS NS
H.sapiens(pooled)	30.2	1.42	5.1	21.7	40.6	16.9	13	31.7	1.20	4.5	22.8	36.7	14.2	14	105	NS NS

H(ii): Root robusticity index

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t F
$3RP^3$ l																
Gorilla	37.8	1.17	5.5	26.8	48.9	14.6	22	39.1	2.11	8.7	29.9	57.9	22.2	17	103	NS NS
Pan	30.1	0.93	3.9	23.1	37.2	13.1	18	30.5	1.33	4.0	25.0	36.1	13.1	9	101	NS NS
Pongo	26.5	1.40	5.2	19.2	36.0	19.8	14	24.5	1.01	3.2	21.7	31.7	13.1	10	93	NS NS
$3RP^3$ mb																
Gorilla	23.7	1.29	6.1	13.9	38.4	25.6	22	25.1	1.10	4.5	18.0	32.6	18.1	17	106	NS NS
Pan	23.6	1.01	4.3	16.2	29.?	18.1	18	29.0	2.05	6.2	18.8	36.7	21.2	9	123	<.05 NS
Pongo	19.4	1.04	3.9	11.7	26.5	20.1	14	18.5	1.43	4.5	11.7	24.6	24.3	10	95	NS NS
$3RP^3$ db																
Gorilla	19.9	0.83	3.9	15.1	31.2	19.5	22	20.9	1.11	4.6	12.1	31.3	21.8	17	105	NS NS
Pan	23.7	1.20	5.1	18.0	39.3	21.4	18	23.7	1.52	4.6	18.4	34.1	19.3	9	100	NS NS
Pongo	16.7	0.96	3.6	13.1	25.2	21.5	14	17.4	1.10	3.5	13.3	22.9	20.1	10	104	NS NS
$2RP^3$ l																
Pan	27.9	-	-	-	-	-	1	32.4	-	-	26.0	38.9	-	2	-	- -
Pongo	-	-	-	-	-	-	-	24.5	-	-	20.6	28.5	-	2	-	- -
H.sapiens(pooled)	29.1	-	-	27.5	31.8	-	4	22.2	-	-	-	-	-	1	-	- -
$2RP^3$ b																
Pan	32.0	-	-	-	-	-	1	34.3	-	-	34.1	34.4	-	2	-	- -
Pongo	-	-	-	-	-	-	-	22.4	-	-	22.3	22.4	-	2	-	- -
H.sapiens(pooled)	24.3	-	-	20.7	27.9	-	4	20.5	-	-	-	-	-	1	-	- -

H(11) : Root robusticity index

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t F
1RP3																
H.sapiens(pooled)	23.1	0.85	2.9	19.1	29.1	12.7	12	22.8	0.63	2.4	18.6	27.8	10.3	14	99	NS NS
3RP4 1																
Gorilla	42.9	1.06	5.1	35.7	51.8	11.8	23	44.5	2.11	8.7	33.7	63.9	19.5	17	104	NS <.05
Pan	32.3	-	-	31.1	33.1	-	3	34.2	-	-	27.7	40.6	-	2	106	- -
Pongo	28.3	1.32	5.3	19.8	38.1	18.7	16	28.7	2.03	6.7	20.7	41.4	23.4	11	101	NS NS
3RP4 mb																
Gorilla	21.1	0.89	4.3	13.7	27.6	20.3	23	22.1	1.45	6.0	11.6	37.6	27.1	17	105	NS NS
Pan	19.9	-	-	18.3	22.5	-	3	21.5	-	-	18.0	25.0	-	2	108	- -
Pongo	16.5	0.67	2.7	11.7	20.7	16.2	16	18.0	1.08	3.6	10.0	23.4	19.8	11	109	NS NS
3RP4 db																
Gorilla	20.3	0.74	3.6	13.3	27.5	17.5	23	21.2	1.17	4.8	10.1	29.4	22.7	17	104	NS NS
Pan	21.0	-	-	19.6	23.2	-	3	23.2	-	-	22.8	23.7	-	2	111	- -
Pongo	19.6	0.63	2.5	15.2	24.7	12.9	16	19.3	1.23	4.1	11.7	26.9	21.1	11	99	NS NS
2RP4 1																
Pan	32.7	1.00	4.1	27.6	40.9	12.7	17	34.2	2.11	6.0	26.8	44.9	17.4	8	105	NS NS
Pongo	29.0	-	-	-	-	-	1	25.6	-	-	-	-	-	1	-	- -
2RP4 b																
Pan	26.3	1.24	5.1	18.6	34.7	19.4	17	30.4	2.43	6.9	20.8	37.9	22.6	8	116	NS NS
Pongo	21.6	-	-	-	-	-	1	22.5	-	-	-	-	-	1	-	- -

H(ii): Root robusticity index

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t F
IRP^4																
H.sapiens(pooled)	22.5	0.75	3.0	16.0	27.7	13.3	16	22.7	0.61	2.4	19.1	27.5	10.8	16	101	NS NS
M^1 l																
Gorilla	53.6	1.96	9.4	39.4	73.6	17.5	23	50.2	1.59	6.6	38.7	62.1	13.1	17	94	NS NS
Pan	38.9	1.39	6.2	24.6	50.0	16.0	20	41.1	1.80	6.0	31.8	52.3	14.5	11	106	NS NS
Pongo	42.8	1.78	7.6	35.3	59.4	17.7	18	44.0	1.49	5.6	30.3	55.0	12.7	14	103	NS NS
H.sapiens(pooled)	37.5	1.11	4.3	29.4	44.0	11.5	15	35.5	1.46	5.8	24.4	47.3	16.5	16	95	NS NS
M^1 mb																
Gorilla	28.1	0.94	4.5	18.2	36.8	16.0	23	26.9	1.98	8.2	17.0	48.3	30.4	17	96	NS .01
Pan	29.1	1.42	6.3	19.0	41.0	21.8	20	29.7	1.05	3.5	23.7	34.7	11.8	11	102	NS NS
Pongo	22.4	0.95	4.0	17.2	29.0	18.0	18	22.5	1.33	5.0	15.0	31.3	22.2	14	101	NS NS
H.sapiens(pooled)	24.9	1.00	3.9	18.6	33.0	15.6	15	25.8	1.08	4.3	19.6	36.9	16.7	16	104	NS NS
M^1 db																
Gorilla	29.1	1.06	5.1	21.8	38.2	17.5	23	25.6	0.84	3.5	19.7	31.3	13.5	17	88	<.05 NS
Pan	27.1	1.15	5.2	19.4	38.0	19.0	20	27.9	1.33	4.4	23.1	35.4	15.8	11	103	NS NS
Pongo	22.3	0.96	4.1	16.1	30.9	18.3	18	22.3	0.98	3.7	18.2	28.6	16.4	14	100	NS NS
H.sapiens(pooled)	24.4	0.69	2.7	20.0	27.7	11.0	15	25.0	1.24	4.9	16.7	32.6	19.8	16	103	NS <.05
M^2 l																
Gorilla	65.3	2.08	9.5	50.0	88.8	14.6	21	61.2	2.35	9.1	48.7	77.3	14.9	15	94	NS NS
Pan	43.3	1.33	5.9	32.1	53.1	13.7	20	44.8	2.31	7.3	30.4	54.1	16.3	10	104	NS NS
Pongo	45.7	2.18	8.2	27.7	58.0	17.8	14	46.3	2.24	8.7	35.0	65.3	18.7	15	101	NS NS
H.sapiens(pooled)	32.0	1.30	5.0	23.2	40.9	15.7	15	35.8	1.24	4.5	29.2	46.7	12.5	13	112	<.05 NS

H(ii): Root robusticity index

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t F
M^2 mb																
Gorilla	27.9	1.04	4.8	20.0	36.2	17.1	21	26.5	1.22	4.7	18.3	33.3	17.8	15	95	NS NS
Pan	26.7	0.74	3.3	20.7	33.8	12.4	20	31.3	1.47	4.7	25.2	38.5	14.9	10	117	<.01 NS
Pongo	23.6	1.25	4.7	18.2	33.3	19.8	14	25.8	1.46	5.6	17.8	37.3	21.8	15	109	NS NS
H.sapiens(pooled)	23.8	1.01	3.9	18.4	33.3	16.4	15	22.6	0.79	2.9	16.7	26.6	12.6	13	95	NS NS
M^2 db																
Gorilla	29.0	1.50	6.9	19.1	43.2	23.7	21	30.5	1.84	7.1	17.6	45.7	23.3	15	105	NS NS
Pan	25.2	1.13	5.0	15.6	35.9	20.0	20	29.4	1.47	4.7	22.1	38.0	15.8	10	117	<.05 NS
Pongo	23.4	1.27	4.7	18.5	35.3	20.2	14	23.6	1.14	4.4	17.9	32.1	18.8	15	101	NS NS
H.sapiens(pooled)	23.8	0.80	3.1	19.3	30.7	13.1	15	23.3	1.12	4.0	16.8	28.6	17.3	13	98	NS NS
M^3 l																
Gorilla	56.2	1.69	8.1	37.8	71.2	14.4	23	53.8	2.09	7.8	42.1	65.0	14.5	14	96	NS NS
Pan	41.1	1.48	6.6	32.1	58.8	16.1	20	42.2	2.19	6.9	26.3	53.0	16.4	10	103	NS NS
Pongo	42.8	2.39	8.6	33.0	59.0	20.1	13	52.2	1.86	6.2	41.1	61.6	11.8	11	122	<.01 NS
H.sapiens(pooled)	32.8	2.09	5.1	25.8	41.4	15.6	6	36.9	2.58	6.3	25.0	43.0	17.1	6	113	NS NS
M^3 mb																
Gorilla	27.3	0.84	4.0	18.3	39.3	14.8	23	28.8	1.43	5.4	21.5	38.7	18.6	14	106	NS NS
Pan	28.6	0.91	4.1	21.1	37.7	14.2	20	28.6	1.63	5.1	20.8	38.8	18.0	10	100	NS NS
Pongo	22.6	1.18	4.2	16.9	28.3	18.8	13	29.5	0.94	3.1	24.5	34.6	10.6	11	131	<.001 NS
H.sapiens(pooled)	24.3	1.79	4.4	19.6	32.3	18.1	6	24.5	2.42	5.9	15.0	32.4	24.1	6	101	NS NS

H(ii): Root robusticity index

	Males							Females							P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t F
M^3 db																
Gorilla	28.6	0.98	4.7	20.0	36.8	16.5	23	27.6	1.32	5.0	19.6	36.7	17.9	14	97	NS NS
Pan	26.8	1.66	7.4	15.8	49.2	27.6	20	29.2	1.30	4.1	24.8	36.6	14.1	10	109	NS NS
Pongo	25.2	1.62	5.8	14.7	36.3	23.2	13	29.8	1.59	5.3	21.9	39.6	17.7	11	118	NS NS
H.sapiens(pooled)	21.1	1.65	4.1	13.3	24.6	19.2	6	23.2	1.63	4.0	15.5	27.1	17.2	6	110	NS NS

H(111) : Height of bifurcation index

	Males							Females								P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	%SD	t	F
$2RP_{\overline{3}}$																	
Gorilla	20.3	1.84	8.8	7.4	37.4	43.5	23	22.1	1.81	7.2	10.1	32.8	32.7	16	109	NS	NS
Pan	25.5	2.23	8.9	12.9	49.0	34.9	16	29.7	3.89	9.5	18.3	43.4	32.1	6	117	NS	NS
Pongo	26.5	1.64	6.8	9.4	37.2	25.5	17	23.9	1.93	7.0	12.5	34.5	29.1	13	90	NS	NS
H.sapiens(pooled)	48.5	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
$2RP_{\overline{4}}$																	
Gorilla	28.1	1.17	5.5	20.5	40.6	19.6	22	27.8	1.42	5.5	16.8	36.8	19.8	15	99	NS	NS
Pan	30.1	1.26	5.6	22.3	40.2	18.6	20	34.1	4.87	16.2	20.9	77.4	47.5	11	113	NS	<.001
Pongo	21.5	1.22	5.0	15.0	36.5	23.4	17	23.3	1.21	4.67	13.8	34.8	20.1	15	108	NS	NS
$M_{\overline{1}}$																	
Gorilla	18.9	0.68	3.3	14.1	27.4	17.5	23	18.2	0.70	2.9	12.4	23.3	15.8	17	96	NS	NS
Pan	23.5	0.95	4.2	16.8	30.6	18.0	20	22.8	0.81	2.7	18.6	27.2	11.8	11	97	NS	NS
Pongo	21.1	0.82	3.6	16.1	27.9	16.9	19	19.9	0.69	2.7	12.8	22.6	13.5	15	94	NS	NS
H.sapiens(pooled)	29.1	1.18	4.7	21.6	40.0	16.3	16	29.9	0.93	3.8	23.1	36.8	12.9	17	103	NS	NS
$M_{\overline{2}}$																	
Gorilla	21.1	1.03	4.9	13.9	32.4	23.3	23	22.7	0.88	3.5	14.7	28.7	15.5	16	108	NS	NS
Pan	27.4	1.59	7.1	15.6	49.0	26.0	20	24.7	0.98	3.3	20.3	30.0	13.2	11	90	NS	<.05
Pongo	22.2	0.96	3.7	15.4	26.9	16.7	15	21.4	1.14	4.1	13.5	28.4	19.1	13	96	NS	NS
H.sapiens(pooled)	31.1	1.32	5.3	24.0	43.9	16.9	16	31.6	1.46	6.0	24.5	44.6	19.1	17	102	NS	NS

H(iii): Height of bifurcation index

	Males							Females							%SD	P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N		t	F
M_3																	
Gorilla	22.7	1.02	4.5	14.0	30.1	19.6	19	25.5	1.17	4.2	19.0	33.6	16.5	13	112	NS	NS
Pan	34.8	1.50	6.6	22.0	47.3	18.9	19	27.1	1.51	4.8	17.1	33.3	17.6	10	78	<.01	NS
Pongo	25.6	1.31	4.6	19.9	34.2	17.8	12	24.8	1.26	3.3	19.9	29.1	13.5	7	97	NS	NS
H.sapiens(pooled)	35.3	1.98	7.1	26.4	48.7	20.2	13	37.1	1.75	6.6	28.3	54.1	17.7	14	105	NS	NS
$3RP^3$																	
Gorilla	22.0	1.01	4.7	15.1	32.5	21.5	22	22.5	1.96	8.1	8.8	33.1	35.9	17	102	NS	<.05
Pan	31.2	1.90	8.1	13.5	40.9	25.8	18	39.1	3.48	10.5	24.3	56.2	26.7	9	125	<.05	NS
Pongo	29.5	1.98	7.4	20.2	50.0	25.2	14	27.9	1.41	4.5	22.5	36.7	15.9	10	95	NS	NS
$3RP^4$																	
Gorilla	27.3	1.41	6.8	14.2	37.3	24.8	23	28.1	1.02	4.2	20.5	34.0	14.9	17	103	NS	NS
Pan	29.6	-	-	20.4	43.4	-	3	35.9	-	-	29.7	42.1	-	2	121	-	-
Pongo	29.5	2.03	8.1	19.6	48.3	27.5	16	31.6	1.52	5.0	24.5	42.8	15.9	11	107	NS	NS
M^1																	
Gorilla	18.6	1.85	8.9	7.5	50.7	47.9	23	16.2	1.47	6.1	6.2	28.7	37.5	17	87	NS	NS
Pan	22.9	1.40	6.3	13.5	37.8	27.4	20	26.1	1.70	5.6	18.0	34.4	21.6	11	114	NS	NS
Pongo	24.5	1.63	6.9	14.2	37.5	28.3	18	23.7	1.72	6.4	14.3	35.8	27.1	14	97	NS	NS
H.sapiens(pooled)	32.3	2.10	8.1	19.9	48.2	25.2	15	30.3	1.76	7.0	20.9	44.4	23.2	16	94	NS	NS
M^2																	
Gorilla	17.7	1.45	6.7	7.5	33.2	37.6	21	19.0	2.06	8.0	6.4	37.6	42.0	15	107	NS	NS
Pan	24.5	1.76	7.9	9.4	36.4	32.2	20	27.6	3.22	10.2	10.6	41.0	36.9	10	113	NS	NS
Pongo	24.3	1.40	5.2	17.0	34.4	21.5	14	22.8	1.29	5.0	16.2	32.1	21.9	15	94	NS	NS
H.sapiens(pooled)	36.1	2.90	11.2	21.4	62.8	31.1	15	34.5	1.91	6.9	25.4	47.7	20.0	13	96	NS	NS

H(iii): Height of bifurcation index

	Males							Females							%SD	P	
	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N		t	F
M^3																	
Gorilla	19.6	1.55	7.5	6.3	31.9	38.0	23	23.5	2.30	8.6	11.9	36.3	36.5	14	120	NS	NS
Pan	30.9	1.76	7.9	17.6	51.7	25.5	20	34.4	3.35	10.6	20.2	52.3	30.8	10	111	NS	NS
Pongo	25.1	3.00	10.8	8.5	44.5	43.2	13	23.7	1.77	5.9	14.6	30.5	24.7	11	94	NS	NS
H.sapiens(pooled)	34.0	1.92	4.7	25.4	39.2	13.9	6	39.7	1.94	4.7	33.6	45.7	11.9	6	117	NS	NS

H(iv): Root divergence

	Males						Females						P	
	$\bar{X}$	S.E.	S.D.	min	max	N	$\bar{X}$	S.E.	S.D.	min	max	N	t	F
$2RP_3$														
Gorilla	-6	1.30	6.2	-21	+3	23	-8	1.24	5.0	-23	-1	16	NS	NS
Pan	-2	1.62	6.5	-13	+9	16	0	2.12	5.2	-6	+7	6	NS	NS
Pongo	0	1.03	4.2	-10	+7	17	+1	1.76	6.3	-5	+14	13	NS	NS
H.sapiens(pooled)	-6	-	-	-	-	1	-	-	-	-	-	-	-	-
$2RP_4$														
Gorilla	+4	1.11	5.2	-6	+14	22	+4	1.16	4.5	-3	+14	15	NS	NS
Pan	+7	1.55	6.9	-8	+19	20	+4	1.91	6.3	-5	+15	11	NS	NS
Pongo	+5	1.22	5.0	-6	+11	17	+4	2.00	7.7	-10	+18	15	NS	NS
M_1														
Gorilla	+13	1.18	5.7	+4	+28	23	+13	1.03	4.2	+6	+20	17	NS	NS
Pan	+11	1.59	7.1	-2	+29	20	+6	0.99	3.3	+2	+10	11	<.01	<.05
Pongo	+8	1.20	5.2	-1	+17	19	+7	1.15	4.4	-1	+15	15	NS	NS
H.sapiens(pooled)	+8	1.54	6.2	0	+18	16	+7	1.69	7.0	-5	+22	17	NS	NS
M_2														
Gorilla	+10	1.11	5.3	+2	+21	23	+10	0.95	3.8	+1	+18	16	NS	NS
Pan	+8	1.22	5.4	-2	+17	20	+10	1.60	5.3	+1	+19	11	NS	NS
Pongo	+7	1.23	4.8	+1	+17	15	+9	1.81	6.5	-1	+20	13	NS	NS
H.sapiens(pooled)	-1	1.21	4.8	-11	+6	16	0	1.47	6.1	-13	+11	17	NS	NS

H(iv): Root divergence

	Males						Females						P	
	$\bar{X}$	S.E.	S.D.	min	max	N	$\bar{X}$	S.E.	S.D.	min	max	N	t	F
M_3														
Gorilla	+17	1.34	5.9	+6	+29	19	+14	1.53	5.5	+4	+22	13	NS	NS
Pan	+14	2.04	8.9	-6	+27	19	+15	1.02	3.2	+8	+20	10	NS	<.01
Pongo	+9	1.54	5.3	+4	+20	12	+12	2.57	6.8	+4	+24	7	NS	NS
H.sapiens(pooled)	-2	1.88	6.8	-16	+8	13	-3	1.58	5.9	-11	+8	14	NS	NS
$3RP^3$														
Gorilla	+11	1.76	8.3	-7	+25	22	+8	2.04	8.4	-9	+19	17	NS	NS
Pan	+12	1.76	7.4	+1	+27	18	+12	2.26	6.8	+5	+27	9	NS	NS
Pongo	+9	1.46	5.4	+2	+24	14	+9	2.92	9.2	-5	+28	10	NS	NS
$3RP^4$														
Gorilla	+8	1.86	8.9	-9	+26	23	+13	1.87	7.7	0	+26	17	NS	NS
Pan	+10	-	-	+4	+18	3	+3	-	-	+1	+5	2	-	-
Pongo	+6	1.36	5.4	-4	+14	16	+6	1.41	4.7	-1	+13	11	NS	NS
M^1														
Gorilla	+9	1.94	9.3	-3	+28	23	+9	1.87	7.7	-4	+23	17	NS	NS
Pan	+14	1.75	7.8	+3	+29	20	+11	2.22	7.4	-5	+22	11	NS	NS
Pongo	0	1.82	7.7	-11	+15	18	+2	1.94	7.3	-11	+14	14	NS	NS
H.sapiens(pooled)	+7	1.64	6.4	-4	+19	15	+6	1.79	7.2	-7	+21	16	NS	NS

H(iv): Root divergence

	Males						Females						P	
	$\bar{X}$	S.E.	S.D.	min	max	N	$\bar{X}$	S.E.	S.D.	min	max	N	t	F
M^2														
Gorilla	-1	1.48	6.8	-14	+12	21	0	2.04	7.9	-10	+21	15	NS	NS
Pan	+11	2.06	9.2	-3	+37	20	+8	2.53	8.0	-5	+23	10	NS	NS
Pongo	+2	1.96	7.3	-10	+14	14	+3	1.82	7.0	-9	+14	15	NS	NS
H.sapiens(pooled)	+2	1.73	6.7	-9	+17	15	+2	2.34	8.4	-10	+20	13	NS	NS
M^3														
Gorilla	+5	1.71	8.2	-12	+18	23	+3	1.85	6.9	-10	+15	14	NS	NS
Pan	+17	3.12	14.0	-1	+44	20	+10	3.25	10.3	-3	+26	10	NS	NS
Pongo	+16	3.30	11.9	-1	+41	13	+19	2.95	9.8	+8	+41	11	NS	NS
H.sapiens(pooled)	+2	3.27	8.0	-8	+13	6	+4	3.19	7.8	-11	+11	6	NS	NS

Appendix I : Correlation coefficients computed between root height and other root, crown and jaw variables in the pongids and Homo sapiens

I (i) : actual root height - inter-root/inter-tooth

I (ii) : actual root height/root mesiodistal diameter

I (iii) : actual root height/neck mesiodistal diameter

I (iv) : actual root height/location of bifurcation

I (v) : actual root height/projected root height

I (vi) : actual root height/height of bifurcation

I (vii) : actual root height/root angulation

I (viii) : actual root height/crown mesiodistal diameter

I (ix) : actual root height/crown buccolingual diameter

I (x) : actual root height/crown area

I (xi) : actual root height/mandibular length

I (xii) : actual root height/mandibular depth

I (xiii) : actual root height/palatal dimensions

I (xiv) : actual root height/palatal index

I (i) : actual root height - inter-root/inter-tooth

	Gorilla			Pan			Pongo			H.sapiens		
	r	N	P	r	N	P	r	N	P	r	N	P
$I_{\bar{1}}-I_{\bar{2}}$	0.82	28	<.001	0.78	25	<.001	0.77	29	<.001	0.64	24	<.001
$I_{\bar{2}}-C_{\bar{1}}$	0.65	29	<.001	0.39	23	<.05	0.45	14	NS	0.73	29	<.001
$C_{\bar{1}}-P_{\bar{3}}m$	0.30	30	NS	0.56	19	<.01	0.68	15	<.01	0.80	29	<.001
$P_{\bar{3}}m-P_{\bar{3}}d$	0.91	39	<.001	0.91	22	<.001	0.89	30	<.001	-	-	-
$P_{\bar{3}}d-P_{\bar{4}}m$	0.55	37	<.001	0.81	22	<.001	0.81	30	<.001	0.84	30	<.001
$P_{\bar{4}}m-P_{\bar{4}}d$	0.87	37	<.001	0.93	31	<.001	0.91	32	<.001	-	-	-
$P_{\bar{4}}d-M_{\bar{1}}m$	0.30	38	<.05	0.71	31	<.001	0.74	32	<.001	0.79	32	<.001
$M_{\bar{1}}m-M_{\bar{1}}d$	0.86	40	<.001	0.86	31	<.001	0.96	34	<.001	0.94	33	<.001
$M_{\bar{1}}d-M_{\bar{2}}m$	0.74	40	<.001	0.78	31	<.001	0.91	31	<.001	0.80	32	<.001
$M_{\bar{2}}m-M_{\bar{2}}d$	0.83	39	<.001	0.93	31	<.001	0.92	28	<.001	0.94	33	<.001
$M_{\bar{2}}d-M_{\bar{3}}m$	0.70	37	<.001	0.74	31	<.001	0.92	19	<.001	0.49	26	<.01
$M_{\bar{3}}m-M_{\bar{3}}d$	0.84	32	<.001	0.80	29	<.001	0.95	19	<.001	0.88	27	<.001
$I_{\underline{1}}-I_{\underline{2}}$	0.77	22	<.001	0.66	24	<.001	0.80	28	<.001	0.79	23	<.001
$P_{\underline{3}}mb-P_{\underline{3}}l$	0.65	39	<.001	0.69	27	<.001	0.60	24	<.001	-	-	-
$P_{\underline{3}}db-P_{\underline{3}}l$	0.56	39	<.001	0.48	27	<.01	0.67	24	<.001	-	-	-
$P_{\underline{3}}mb-P_{\underline{3}}db$	0.80	39	<.001	0.67	27	<.001	0.76	24	<.001	-	-	-
$P_{\underline{4}}mb-P_{\underline{4}}l$	0.63	40	<.001	0.58	5	NS	0.79	27	<.001	-	-	-
$P_{\underline{4}}db-P_{\underline{4}}l$	0.68	40	<.001	0.50	5	NS	0.77	27	<.001	-	-	-
$P_{\underline{4}}mb-P_{\underline{4}}db$	0.91	40	<.001	0.98	5	<.01	0.93	27	<.001	-	-	-
$P_{\underline{4}}b-P_{\underline{4}}l$	-	-	-	0.76	25	<.001	-	-	-	-	-	-

I (i) : actual root height - inter-root/inter-tooth

	Gorilla			Pan			Pongo			H.sapiens		
	r	N	P	r	N	P	r	N	P	r	N	P
M^1mb-M^1l	0.25	40	NS	0.61	31	<.001	0.38	32	<.05	0.35	31	<.05
M^1db-M^1l	0.32	40	<.05	0.67	31	<.001	0.42	32	<.01	0.42	31	<.01
M^1mb-M^1db	0.75	40	<.001	0.84	31	<.001	0.90	32	<.001	0.83	31	<.001
M^2mb-M^2l	0.40	36	<.01	0.65	30	<.001	0.55	29	.001	0.52	28	<.01
M^2db-M^2l	0.42	36	<.01	0.58	30	<.001	0.49	29	<.01	0.56	28	.001
M^2mb-M^2db	0.85	36	<.001	0.83	30	<.001	0.97	29	<.001	0.80	28	<.001
M^3mb-M^3l	0.53	37	<.001	0.50	30	<.01	0.71	24	<.001	0.78	12	.001
M^3db-M^3l	0.45	37	<.01	0.42	30	<.05	0.55	24	<.01	0.83	12	<.001
M^3mb-M^3db	0.75	37	<.001	0.76	30	<.001	0.83	24	<.001	0.97	12	<.001
C_1-P_3 av	0.32	30	<.05	0.56	19	<.01	0.72	15	<.01	-	-	-
P_3 av-P_4 av	0.63	37	<.001	0.91	22	<.001	0.84	30	<.001	-	-	-
P_4 av-M_1 av	0.40	37	<.01	0.75	31	<.001	0.78	32	<.001	0.83	32	<.001
M_1 av-M_2 av	0.83	39	<.001	0.81	31	<.001	0.89	28	<.001	0.82	32	<.001
M_2 av-M_3 av	0.83	32	<.001	0.77	29	<.001	0.83	19	<.001	0.58	26	.001
P^3 av-P^4 av	0.85	39	<.001	0.67	5	NS	0.88	21	<.001	0.87	25	<.001
P^4 av-M^1 av	0.69	40	<.001	0.76	25	<.001	0.82	26	<.001	0.71	30	<.001
M^1 av-M^2 av	0.68	36	<.001	0.82	30	<.001	0.87	28	<.001	0.65	26	<.001
M^2 av-M^3 av	0.71	35	<.001	0.64	29	<.001	0.71	22	<.001	0.78	10	<.01

I (ii) : actual root height/root mesiodistal diameter

	Gorilla			Pan			Pongo			H.sapiens		
	r	N	P	r	N	P	r	N	P	r	N	P
$C_{\bar{1}}$	0.65	30	<.001	0.74	27	<.001	0.65	15	<.01	0.26	31	NS
$2RP_{\bar{3}}m$	0.49	39	<.001	0.50	22	<.01	0.20	30	NS	-	-	-
$2RP_{\bar{3}}d$	0.47	39	.001	0.46	22	<.05	0.39	30	<.05	-	-	-
$1RP_{\bar{3}}$	-	-	-	-0.28	9	NS	-	-	-	0.44	31	<.01
$2RP_{\bar{4}}m$	0.32	37	<.05	0.29	30	NS	0.12	32	NS	-	-	-
$2RP_{\bar{4}}d$	0.40	38	<.01	0.18	30	NS	0.21	32	NS	-	-	-
$1RP_{\bar{4}}$	-	-	-	-	-	-	-	-	-	0.26	33	NS
$M_{\bar{1}}m$	0.13	40	NS	0.22	31	NS	0.31	34	<.05	0.46	33	<.01
$M_{\bar{1}}d$	0.24	40	NS	0.47	31	<.01	0.13	34	NS	0.62	33	<.001
$M_{\bar{2}}m$	0.24	40	NS	0.36	31	<.05	0.17	31	NS	0.45	33	<.01
$M_{\bar{2}}d$	0.34	39	<.01	0.36	31	<.05	0.18	28	NS	0.40	33	<.01
$M_{\bar{3}}m$	0.19	37	NS	0.37	31	<.05	0.19	20	NS	0.53	27	<.01
$M_{\bar{3}}d$	0.22	32	NS	0.27	29	NS	-0.39	19	NS	0.55	27	<.01
$3RP^{\bar{3}}1$	0.37	39	.01	0.59	27	<.001	0.09	24	NS	-	-	-
$3RP^{\bar{3}}mb$	0.28	39	<.05	0.27	27	NS	0.17	24	NS	-	-	-
$3RP^{\bar{3}}db$	0.35	39	<.05	0.30	27	NS	-0.02	24	NS	-	-	-
$1RP^{\bar{3}}$	-	-	-	-	-	-	-	-	-	0.76	26	<.001
$3RP^{\bar{4}}1$	0.34	40	<.05	0.78	5	NS	0.06	27	NS	-	-	-
$3RP^{\bar{4}}mb$	0.18	40	NS	0.61	5	NS	0.26	27	NS	-	-	-
$3RP^{\bar{4}}db$	0.01	40	NS	0.84	5	<.05	0.30	27	NS	-	-	-

I (ii) : actual root height/root mesiodistal diameter

	Gorilla			Pan			Pongo			H.sapiens		
	r	N	P	r	N	P	r	N	P	r	N	P
$2RP^{4}_{-}l$	-	-	-	0.53	25	<.01	-	-	-	-	-	-
$2RP^{4}_{-}b$	-	-	-	0.12	25	NS	-	-	-	-	-	-
$1RP^{4}_{-}$	-	-	-	-	-	-	-	-	-	0.60	32	<.001
$M^{1}_{-}l$	0.08	40	NS	0.29	31	NS	-0.02	32	NS	0.36	31	<.05
$M^{1}_{-}mb$	-0.02	40	NS	0.29	31	NS	0.12	32	NS	0.31	31	<.05
$M^{1}_{-}db$	0.35	40	<.05	0.45	31	<.01	0.37	32	<.05	0.28	31	NS
$M^{2}_{-}l$	0.35	36	<.05	0.42	30	<.05	0.15	29	NS	0.36	28	<.05
$M^{2}_{-}mb$	0.45	36	<.01	0.56	30	<.001	-0.15	29	NS	0.31	28	NS
$M^{2}_{-}db$	-0.01	36	NS	0.19	30	NS	0.34	29	<.05	0.44	28	<.01
$M^{3}_{-}l$	0.48	37	<.01	0.11	30	NS	0.08	24	NS	0.43	12	NS
$M^{3}_{-}mb$	0.46	37	<.01	0.48	30	<.01	0.05	24	NS	0.44	12	NS
$M^{3}_{-}db$	0.63	37	<.001	0.15	30	NS	0.16	24	NS	0.17	12	NS

I (iii) : actual root height/neck mesiodistal diameter

	Gorilla			Pan			Pongo			H.sapiens		
	r	N	P	r	N	P	r	N	P	r	N	P
$I_{\bar{1}}$	0.49	28	<.01	-0.13	26	NS	0.54	31	<.001	0.45	25	<.05
$I_{\bar{2}}$	0.51	36	<.001	0.25	26	NS	0.38	31	<.05	0.35	30	<.05
$C_{\bar{1}}$	0.69	30	<.001	0.66	27	<.001	0.69	15	<.01	0.39	31	<.05
$2RP_{\bar{3}}m$	0.40	39	<.01	0.27	22	NS	0.33	30	<.05	-	-	-
$2RP_{\bar{3}}d$	0.42	39	<.01	0.39	22	<.05	0.35	30	<.05	-	-	-
$1RP_{\bar{3}}$	-	-	-	-	-	-	-	-	-			
$2RP_{\bar{4}}m$	0.46	37	<.01	-0.01	31	NS	0.40	32	<.05	-	-	-
$2RP_{\bar{4}}d$	0.39	38	<.01	0.01	31	NS	0.30	32	.05	-	-	-
$1RP_{\bar{4}}$	-	-	-	-	-	-	-	-	-			
$M_{\bar{1}}m$	0.46	40	<.01	0.04	31	NS	0.56	34	<.001	0.70	33	<.001
$M_{\bar{1}}d$	0.35	40	<.05	0.07	31	NS	0.50	34	.001	0.64	33	<.001
$M_{\bar{2}}m$	0.61	40	<.001	-0.03	31	NS	0.55	31	<.001	0.71	33	<.001
$M_{\bar{2}}d$	0.53	39	<.001	-0.01	31	NS	0.48	28	<.01	0.71	33	<.001
$M_{\bar{3}}m$	0.43	37	<.01	0.03	31	NS	0.38	20	.05	0.46	27	<.01
$M_{\bar{3}}d$	0.44	32	<.01	0.03	29	NS	0.35	19	NS	0.48	27	<.01

I (iv) : actual root height/location of bifurcation

	Gorilla			Pan			Pongo			H.sapiens		
	r	N	P	r	N	P	r	N	P	r	N	P
$2RP_3^-m$	0.45	39	<.01	0.35	22	NS	0.25	30	NS	-	-	-
$2RP_3^-d$	0.14	39	NS	0.22	22	NS	0.31	30	.05	-	-	-
$2RP_4^-m$	0.40	37	<.01	0.20	31	NS	0.45	32	<.01	-	-	-
$2RP_4^-d$	0.30	38	<.01	-0.09	31	NS	0.15	32	NS	-	-	-
M_1^-m	0.52	40	<.001	0.20	31	NS	0.50	34	<.01	0.48	33	<.01
M_1^-d	0.19	40	NS	-0.08	31	NS	0.31	34	<.05	0.64	33	<.001
M_2^-m	0.52	40	<.001	-0.03	31	NS	0.49	31	<.01	0.60	33	<.001
M_2^-d	0.40	39	<.01	-0.03	31	NS	0.29	28	NS	0.61	33	<.001
M_3^-m	0.49	37	.001	0.39	31	<.05	0.53	20	<.01	0.41	27	<.05
M_3^-d	0.30	32	.05	0.18	29	NS	-0.01	19	NS	0.26	27	NS

*for distal roots, actual root height correlated with (neck mesiodistal diameter - location of bifurcation)

I (v) : actual root height/projected root height

	Gorilla			Pan			Pongo			H.sapiens		
	r	N	P	r	N	P	r	N	P	r	N	P
I_1^-	1.00	28	<.001	1.00	26	<.001	1.00	31	<.001	1.00	25	<.001
I_2^-	0.98	36	<.001	0.99	26	<.001	0.98	31	<.001	1.00	30	<.001
$2RP_3^-m$	0.99	39	<.001	0.99	22	<.001	0.99	30	<.001	-	-	-
$2RP_3^-d$	1.00	39	<.001	1.00	22	<.001	1.00	30	<.001	-	-	-
$1RP_3^-$	-	-	-	0.92	9	<.001	-	-	-	1.00	31	<.001
$2RP_4^-m$	1.00	37	<.001	1.00	31	<.001	1.00	32	<.001	-	-	-
$2RP_4^-d$	0.99	38	<.001	1.00	31	<.001	0.99	32	<.001	-	-	-
$1RP_4^-$	-	-	-	-	-	-	-	-	-	1.00	33	<.001
M_1^-m	1.00	40	<.001	1.00	31	<.001	1.00	34	<.001	1.00	33	<.001
M_1^-d	0.97	40	<.001	0.99	31	<.001	0.99	34	<.001	1.00	33	<.001
M_2^-m	1.00	40	<.001	1.00	31	<.001	1.00	31	<.001	0.99	33	<.001
M_2^-d	0.99	39	<.001	1.00	31	<.001	1.00	28	<.001	1.00	33	<.001
M_3^-m	1.00	37	<.001	1.00	31	<.001	1.00	20	<.001	0.98	27	<.001
M_3^-d	0.94	32	<.001	0.99	29	<.001	0.99	19	<.001	0.98	27	<.001

I (vi) : actual root height/height of bifurcation

	Gorilla			*Pan*			*Pongo*			H.sapiens		
	r	N	P	r	N	P	r	N	P	r	N	P
$2RP_3^-m$	0.26	39	NS	0.28	22	NS	0.44	30	<.01	-	-	-
$2RP_3^-d$	0.33	39	<.05	0.30	22	NS	0.62	30	<.001	-	-	-
$2RP_4^-m$	0.32	37	<.05	0.21	31	NS	0.37	32	<.05	-	-	-
$2RP_4^-d$	0.25	38	NS	0.12	31	NS	0.54	32	<.001	-	-	-
M_1^-m	0.55	40	<.001	0.15	31	NS	0.52	34	<.001	0.36	33	<.05
M_1^-d	0.41	40	<.01	0.25	31	NS	0.54	34	<.001	0.40	33	.01
M_2^-m	0.11	40	NS	0.14	31	NS	0.51	31	<.01	0.19	33	NS
M_2^-d	0.10	39	NS	0.22	31	NS	0.53	28	<.01	0.26	33	NS
M_3^-m	0.37	37	<.05	0.67	31	<.001	0.59	20	<.01	0.42	27	<.05
M_3^-d	0.26	32	NS	0.56	29	<.001	0.56	19	<.01	0.50	27	<.01

I (vii) : actual root height/root angulation

	Gorilla			Pan			Pongo			H.sapiens		
	r	N	P	r	N	P	r	N	P	r	N	P
I_1^-	-0.23	28	NS	-0.18	26	NS	-0.04	31	NS	-0.37	25	<.05
I_2^-	0.02	36	NS	-0.09	26	NS	0.25	31	NS	-0.03	30	NS
$2RP_3^-m$	0.00	39	NS	0.02	22	NS	0.03	30	NS	-	-	-
$2RP_3^-d$	-0.37	39	<.01	-0.17	22	NS	0.22	30	NS	-	-	-
$1RP_3^-$	-	-	-	-0.66	9	<.05	-	-	-	-0.33	31	<.05
$2RP_4^-m$	-0.25	37	NS	0.10	31	NS	0.07	32	NS	-	-	-
$2RP_4^-d$	0.00	38	NS	-0.69	31	<.001	0.20	32	NS	-	-	-
$1RP_4^-$	-	-	-	-	-	-	-	-	-	-0.32	33	<.05
M_1^-m	-0.19	40	NS	-0.21	31	NS	0.04	34	NS	0.02	33	NS
M_1^-d	0.26	40	NS	-0.22	31	NS	0.02	34	NS	0.04	33	NS
M_2^-m	0.05	40	NS	-0.04	31	NS	0.08	31	NS	-0.32	33	<.05
M_2^-d	0.12	39	NS	-0.06	31	NS	0.10	28	NS	0.34	33	<.05
M_3^-m	0.27	37	NS	0.05	31	NS	-0.46	20	<.05	-0.01	27	NS
M_3^-d	0.05	32	NS	-0.18	29	NS	0.27	19	NS	-0.08	27	NS

I (viii) : actual root height/crown mesiodistal diameter

	Gorilla			Pan			Pongo			H. sapiens		
	r	N	P	r	N	P	r	N	P	r	N	P
I_1^-	0.52	26	<.01	-0.37	26	<.05	0.31	31	<.05	0.30	24	NS
I_2^-	0.45	34	<.01	-0.33	26	<.05	0.14	28	NS	0.03	30	NS
C_1^-	0.65	30	<.001	0.49	27	<.01	0.65	15	<.01	0.72	30	<.001
$2RP_3^-m$	0.30	39	<.05	0.25	22	NS	0.20	30	NS	-	-	-
$2RP_3^-d$	0.30	39	<.05	0.31	22	NS	0.26	30	NS	-	-	-
$1RP_3^-$	-	-	-				-	-	-	0.62	31	<.001
$2RP_4^-m$	0.46	37	<.01	-0.03	31	NS	0.31	32	<.05	-	-	-
$2RP_4^-d$	0.32	38	<.05	-0.05	31	NS	0.30	32	<.05	-	-	-
$1RP_4^-$	-	-	-	-	-	-	-	-	-	0.52	33	.001
M_1^-m	0.49	40	<.001	0.00	31	NS	0.51	33	<.01	0.60	33	<.001
M_1^-d	0.34	40	<.05	-0.07	31	NS	0.46	33	<.01	0.59	33	<.001
M_2^-m	0.52	40	<.001	0.11	30	NS	0.44	31	<.01	0.70	33	<.001
M_2^-d	0.45	39	<.01	0.12	30	NS	0.37	28	<.05	0.70	33	<.001
M_3^-m	0.46	37	<.01	-0.20	31	NS	0.27	20	NS	0.34	27	<.05
M_3^-d	0.36	32	<.05	-0.18	29	NS	0.25	19	NS	0.44	27	<.05
I_1^1	0.50	31	<.01	-0.21	25	NS	0.21	29	NS	0.39	25	<.05
I_2^2	0.45	25	<.05	-0.62	22	.001	0.15	29	NS	0.68	29	<.001
$3RP_1^3$	0.15	39	NS	0.06	27	NS	0.22	24	NS	-	-	-
$3RP_{mb}^3$	-0.02	39	NS	-0.10	27	NS	0.17	24	NS	-	-	-
$3RP_{db}^3$	0.04	39	NS	-0.28	27	NS	0.05	24	NS	-	-	-
$1RP^3$	-	-	-	-	-	-	-	-	-	0.69	26	<.001

I (viii) : actual root height/crown mesiodistal diameter

	Gorilla			Pan			Pongo			H.sapiens		
	r	N	P	r	N	P	r	N	P	r	N	P
$3RP\frac{4}{}1$	0.28	40	<.05	0.30	5	NS	0.25	27	NS	-	-	-
$3RP\frac{4}{}mb$	0.09	40	NS	-0.33	5	NS	0.48	27	<.01	-	-	-
$3RP\frac{4}{}db$	0.15	40	NS	-0.51	5	NS	0.42	27	<.05	-	-	-
$2RP\frac{4}{}1$	-	-	-	0.05	24	NS	-	-	-	-	-	-
$2RP\frac{4}{}b$	-	-	-	0.02	24	NS	-	-	-	-	-	-
$1RP\frac{4}{}$	-	-	-	-	-	-	-	-	-	0.60	32	<.001
$M\frac{1}{}1$	0.20	39	NS	0.21	30	NS	0.22	31	NS	0.33	31	<.05
$M\frac{1}{}mb$	0.15	39	NS	0.32	30	<.05	0.47	31	<.01	0.61	31	<.001
$M\frac{1}{}db$	0.13	39	NS	0.20	30	NS	0.58	31	<.001	0.54	31	<.001
$M\frac{2}{}1$	0.19	36	NS	0.19	29	NS	0.28	29	NS	0.56	28	<.001
$M\frac{2}{}mb$	0.10	36	NS	0.19	29	NS	0.59	29	<.001	0.72	28	<.001
$M\frac{2}{}db$	0.21	36	NS	0.34	29	<.05	0.65	29	<.001	0.73	28	<.001
$M\frac{3}{}1$	0.35	37	<.05	0.12	29	NS	0.25	24	NS	0.69	11	<.01
$M\frac{3}{}mb$	0.29	37	<.05	0.18	29	NS	0.50	24	<.01	0.51	11	NS
$M\frac{3}{}db$	0.27	37	NS	0.34	29	<.05	0.49	24	<.01	0.59	11	<.05
$P\frac{-}{3}$ av	0.31	39	<.05	0.29	22	NS	0.24	30	NS	-	-	-
$P\frac{-}{4}$ av	0.40	37	<.01	-0.04	31	NS	0.31	32	<.05	-	-	-
$M\frac{-}{1}$ av	0.43	40	<.01	-0.03	31	NS	0.49	33	<.01	0.60	33	<.001
$M\frac{-}{2}$ av	0.51	39	<.001	0.12	30	NS	0.40	28	<.05	0.71	33	<.001
$M\frac{-}{3}$ av	0.42	32	<.01	-0.18	29	NS	0.26	19	NS	0.40	27	<.05

I (viii) : actual root height/crown mesiodistal diameter

	Gorilla			Pan			Pongo			H.sapiens		
	r	N	P	r	N	P	r	N	P	r	N	P
P^3 av	0.05	39	NS	-0.13	27	NS	0.16	24	NS	-	-	-
P^4 av	0.17	40	NS	0.03	24	NS	0.41	27	<.05	-	-	-
M^1 av	0.19	39	NS	0.27	30	NS	0.52	31	<.01	0.60	31	<.001
M^2 av	0.19	36	NS	0.27	29	NS	0.58	29	<.001	0.77	28	<.001
M^3 av	0.35	37	<.05	0.26	29	NS	0.46	24	<.05	0.61	11	<.05

I (ix) : actual root height/crown buccolingual diameter

	Gorilla			Pan			Pongo			H.sapiens		
	r	N	P	r	N	P	r	N	P	r	N	P
I_1^-	0.33	25	NS	-0.32	26	NS	0.49	30	<.01	0.17	24	NS
I_2^-	0.49	35	<.01	-0.38	26	<.05	0.30	30	NS	0.21	30	NS
C_1^-	0.65	30	<.001	0.70	27	<.001	0.68	15	<.01	0.63	28	<.001
$2RP_3^-m$	0.13	39	NS	-0.18	22	NS	0.29	30	NS	-	-	-
$2RP_3^-d$	0.29	39	<.05	-0.23	22	NS	0.45	30	<.01	-	-	-
$1RP_3^-$	-	-	-				-	-	-	0.53	31	.001
$2RP_4^-m$	0.49	37	<.01	-0.11	31	NS	0.39	32	<.05	-	-	-
$2RP_4^-d$	0.47	38	<.01	-0.11	31	NS	0.33	32	<.05	-	-	-
$1RP_4^-$	-	-	-	-	-	-	-	-	-	0.57	33	<.001
M_1^-m	0.40	40	<.01	0.17	31	NS	0.51	33	<.01	0.58	33	<.001
M_1^-d	0.32	40	<.05	0.18	31	NS	0.50	33	<.01	0.53	33	<.001
M_2^-m	0.52	40	<.001	-0.11	30	NS	0.49	31	<.01	0.72	33	<.001
M_2^-d	0.42	39	<.01	-0.08	30	NS	0.43	28	<.05	0.66	33	<.001
M_3^-m	0.50	37	<.001	0.11	31	NS	0.50	20	<.05	0.38	27	<.05
M_3^-d	0.32	32	<.05	0.16	29	NS	0.45	19	<.05	0.46	27	<.01
$I^{\underline{1}}$	0.32	29	<.05	-0.31	25	NS	0.30	29	NS	0.50	25	<.01
$I^{\underline{2}}$	0.45	24	<.05	-0.38	22	<.05	0.15	29	NS	0.51	29	<.01
$3RP^{\underline{3}}l$	0.19	39	NS	0.04	27	NS	0.43	24	<.05	-	-	-
$3RP^{\underline{3}}mb$	0.17	39	NS	-0.08	27	NS	0.34	24	NS	-	-	-
$3RP^{\underline{3}}db$	0.19	39	NS	-0.45	27	.01	0.27	24	NS	-	-	-
$1RP^{\underline{3}}$	-	-	-	-	-	-	-	-	-	0.63	26	<.001

I (ix) : actual root height/crown buccolingual diameter

	Gorilla			Pan			Pongo			H.sapiens		
	r	N	P	r	N	P	r	N	P	r	N	P
$3RP\frac{4}{}1$	0.37	40	<.01	0.42	5	NS	0.23	27	NS	-	-	-
$3RP\frac{4}{}mb$	0.27	40	<.05	0.11	5	NS	0.46	27	<.01	-	-	-
$3RP\frac{4}{}db$	0.28	40	<.05	-0.09	5	NS	0.41	27	<.05	-	-	-
$2RP\frac{4}{}1$	-	-	-	0.00	24	NS	-	-	-	-	-	-
$2RP\frac{4}{}b$	-	-	-	0.01	24	NS	-	-	-	-	-	-
$1RP\frac{4}{}$	-	-	-	-	-	-	-	-	-	0.60	32	<.001
$M\frac{1}{}1$	0.18	38	NS	0.15	30	NS	0.21	31	NS	0.39	31	<.05
$M\frac{1}{}mb$	0.08	38	NS	0.30	30	NS	0.41	31	<.05	0.47	31	<.01
$M\frac{1}{}db$	0.12	38	NS	0.14	30	NS	0.46	31	<.01	0.35	31	<.05
$M\frac{2}{}1$	0.13	36	NS	0.20	28	NS	0.23	29	NS	0.50	28	<.01
$M\frac{2}{}mb$	0.22	36	NS	0.05	28	NS	0.50	29	<.01	0.66	28	<.001
$M\frac{2}{}db$	0.39	36	<.01	0.16	28	NS	0.57	29	<.001	0.63	28	<.001
$M\frac{3}{}1$	0.22	37	NS	-0.08	30	NS	0.39	24	<.05	0.56	11	<.05
$M\frac{3}{}mb$	0.21	37	NS	0.01	30	NS	0.54	24	<.01	0.31	11	NS
$M\frac{3}{}db$	0.28	37	<.05	0.07	30	NS	0.55	24	<.01	0.43	11	NS
$P\frac{-}{3}$ av	0.22	39	NS	-0.21	22	NS	0.39	30	<.05	-	-	-
$P\frac{-}{4}$ av	0.50	37	<.001	-0.11	31	NS	0.37	32	<.05	-	-	-
$M\frac{-}{1}$ av	0.37	40	<.01	0.18	31	NS	0.51	33	<.01	0.57	33	<.001
$M\frac{-}{2}$ av	0.49	39	<.001	-0.09	30	NS	0.46	28	<.01	0.70	33	<.001
$M\frac{-}{3}$ av	0.42	32	<.01	0.16	29	NS	0.48	19	<.05	0.43	27	<.05

I (ix) : actual root height/crown buccolingual diameter

	Gorilla			Pan			Pongo			H.sapiens		
	r	N	P	r	N	P	r	N	P	r	N	P
$\frac{P^3}{}$ av	0.21	39	NS	-0.19	27	NS	0.39	24	<.05	-	-	-
$\frac{P^4}{}$ av	0.32	40	<.05	0.01	24	NS	0.40	27	<.05	-	-	-
$\frac{M^1}{}$ av	0.15	38	NS	0.22	30	NS	0.43	31	<.01	0.48	31	<.01
$\frac{M^2}{}$ av	0.31	36	<.05	0.14	28	NS	0.49	29	<.01	0.69	28	<.001
$\frac{M^3}{}$ av	0.27	37	NS	0.01	30	NS	0.55	24	<.01	0.43	11	NS

I (x) : actual root height/crown area

	Gorilla			Pan			Pongo			H.sapiens		
	r	N	P	r	N	P	r	N	P	r	N	P
I_1^-	0.50	24	<.01	-0.40	26	<.05	0.45	30	<.01	0.28	24	NS
I_2^-	0.52	33	.001	-0.44	26	<.05	0.26	28	NS	0.14	30	NS
C_1^-	0.62	30	<.001	0.64	27	<.001	0.71	15	<.01	0.68	28	<.001
$2RP_3^-m$	0.22	39	NS	0.05	22	NS	0.26	30	NS	-	-	-
$2RP_3^-d$	0.33	39	<.05	0.06	22	NS	0.39	30	<.05	-	-	-
$1RP_3^-$	-	-	-				-	-	-	0.61	31	<.001
$2RP_4^-m$	0.51	37	<.001	-0.08	31	NS	0.36	32	<.05	-	-	-
$2RP_4^-d$	0.43	38	<.01	-0.08	31	NS	0.32	32	<.05	-	-	-
$1RP_4^-$	-	-	-	-	-	-	-	-	-	0.57	33	<.001
M_1^-m	0.45	40	<.01	0.10	31	NS	0.53	33	<.001	0.61	33	<.001
M_1^-d	0.34	40	<.05	0.07	31	NS	0.50	33	<.01	0.58	33	<.001
M_2^-m	0.54	40	<.001	-0.01	30	NS	0.48	31	<.01	0.71	33	<.001
M_2^-d	0.45	39	<.01	0.02	30	NS	0.41	28	<.05	0.69	33	<.001
M_3^-m	0.51	37	<.001	-0.05	31	NS	0.41	20	<.05	0.37	27	<.05
M_3^-d	0.36	32	<.05	-0.02	29	NS	0.37	19	NS	0.46	27	<.01
$I^{\underline{1}}$	0.43	29	.01	-0.30	24	NS	0.28	29	NS	0.51	25	<.01
$I^{\underline{2}}$	0.49	24	<.01	-0.61	21	<.01	0.17	29	NS	0.69	29	<.001
$3RP^{\underline{3}}1$	0.19	39	NS	0.06	27	NS	0.38	24	<.05	-	-	-
$3RP^{\underline{3}}mb$	0.09	39	NS	-0.11	27	NS	0.29	24	NS	-	-	-
$3RP^{\underline{3}}db$	0.13	39	NS	-0.44	27	<.05	0.18	24	NS	-	-	-
$1RP^{\underline{3}}$	-	-	-	-	-	-	-	-	-	0.69	26	<.001

I (x) : actual root height/crown area

	Gorilla			Pan			Pongo			H.sapiens		
	r	N	P	r	N	P	r	N	P	r	N	P
$3RP^4_-1$	0.35	40	<.05	0.38	5	NS	0.25	27	NS	-	-	-
$3RP^4_-mb$	0.20	40	NS	-0.15	5	NS	0.49	27	<.01	-	-	-
$3RP^4_-db$	0.24	40	NS	-0.34	5	NS	0.43	27	<.05	-	-	-
$2RP^4_-1$	-	-	-	0.04	24	NS	-	-	-	-	-	-
$2RP^4_-b$	-	-	-	0.01	24	NS	-	-	-	-	-	-
$1RP^4_-$	-	-	-	-	-	-	-	-	-	0.60	32	<.001
M^1_-1	0.21	38	NS	0.22	30	NS	0.22	31	NS	0.37	31	<.05
M^1_-mb	0.14	38	NS	0.36	30	<.05	0.46	31	<.01	0.56	31	<.001
M^1_-db	0.14	38	NS	0.20	30	NS	0.54	31	<.001	0.46	31	<.01
M^2_-1	0.17	36	NS	0.22	28	NS	0.25	29	NS	0.56	28	.001
M^2_-mb	0.18	36	NS	0.15	28	NS	0.57	29	<.001	0.71	28	<.001
M^2_-db	0.33	36	<.05	0.28	28	NS	0.64	29	<.001	0.70	28	<.001
M^3_-1	0.30	37	<.05	0.07	29	NS	0.31	24	NS	0.66	11	<.05
M^3_-mb	0.25	37	NS	0.14	29	NS	0.55	24	<.01	0.42	11	NS
M^3_-db	0.28	37	<.05	0.27	29	NS	0.56	24	<.01	0.54	11	<.05
P_3 av	0.28	39	<.05	0.05	22	NS	0.34	30	<.05	-	-	-
P_4 av	0.49	37	.001	-0.08	31	NS	0.35	32	<.05	-	-	-
M_1 av	0.41	40	<.01	0.09	31	NS	0.52	33	<.001	0.61	33	<.001
M_2 av	0.52	39	<.001	0.00	30	NS	0.44	28	<.01	0.71	33	<.001
M_3 av	0.45	32	<.01	-0.02	29	NS	0.40	19	<.05	0.42	27	<.05

I (x) : actual root height/crown area

	Gorilla			Pan			Pongo			H.sapiens		
	r	N	P	r	N	P	r	N	P	r	N	P
$P^{\underline{3}}$ av	0.15	39	NS	-0.19	27	NS	0.32	24	NS	-	-	-
$P^{\underline{4}}$ av	0.27	40	<.05	0.03	24	NS	0.43	27	<.05	-	-	-
$M^{\underline{1}}$ av	0.20	38	NS	0.29	30	NS	0.49	31	<.01	0.56	31	<.001
$M^{\underline{2}}$ av	0.27	36	NS	0.24	28	NS	0.55	29	<.001	0.76	28	<.001
$M^{\underline{3}}$ av	0.32	37	<.05	0.19	29	NS	0.53	24	<.01	0.55	11	<.05

I (xi) : actual root height/mandibular length

	Gorilla			Pan			Pongo			H.sapiens		
	r	N	P	r	N	P	r	N	P	r	N	P
I_1^-	0.61	28	<.001	0.08	26	NS	0.62	31	<.001	0.69	25	<.001
I_2^-	0.57	36	<.001	-0.13	26	NS	0.56	31	<.001	0.47	30	<.01
C_1^-	0.76	30	<.001	0.62	27	<.001	0.80	15	<.001	0.78	31	<.001
$2RP_3^-m$	0.39	38	<.01	0.18	22	NS	0.45	30	<.01	-	-	-
$2RP_3^-d$	0.47	38	<.01	0.18	22	NS	0.57	30	<.001	-	-	-
$1RP_3^-$	-	-	-	-0.12	9	NS	-	-	-	0.61	31	<.001
$2RP_4^-m$	0.55	36	<.001	0.29	31	NS	0.53	32	<.001	-	-	-
$2RP_4^-d$	0.54	37	<.001	0.27	31	NS	0.54	32	<.001	-	-	-
$1RP_4^-$	-	-	-	-	-	-	-	-	-	0.51	33	.001
M_1^-m	0.49	39	<.001	0.24	31	NS	0.53	34	<.001	0.57	33	<.001
M_1^-d	0.41	39	<.01	0.19	31	NS	0.53	34	<.001	0.55	33	<.001
M_2^-m	0.62	39	<.001	0.12	31	NS	0.55	31	<.001	0.62	33	<.001
M_2^-d	0.58	38	<.001	0.21	31	NS	0.54	28	.001	0.62	33	<.001
M_3^-m	0.52	36	<.001	0.07	31	NS	0.58	20	<.01	0.23	27	NS
M_3^-d	0.42	32	<.01	0.12	29	NS	0.51	19	<.05	0.36	27	<.05
$2RP_3^-$ av	0.44	38	<.01	0.18	22	NS	0.52	30	<.01	-	-	-
$2RP_4^-$ av	0.56	36	<.001	0.29	31	NS	0.55	32	<.001	-	-	-
M_1^- av	0.46	39	<.01	0.23	31	NS	0.53	34	<.001	0.57	33	<.001
M_2^- av	0.63	38	<.001	0.17	31	NS	0.55	28	.001	0.63	33	<.001
M_3^- av	0.49	32	<.01	0.11	29	NS	0.56	19	<.01	0.30	27	NS

I (xii) : actual root height/mandibular depth

	Gorilla			Pan			Pongo			H.sapiens		
	r	N	P	r	N	P	r	N	P	r	N	P
depth C_1^-/I_1^-	0.64	28	<.001	0.26	26	NS	0.47	30	<.01	0.54	25	<.01
I_2^-	0.60	36	<.001	0.42	26	<.05	0.41	30	<.05	0.61	30	<.001
C_1^-	0.71	30	<.001	0.70	27	<.001	0.71	14	<.01	0.56	31	<.001
$2RP_3^-m$	0.49	39	<.001	0.57	22	<.01	0.42	29	<.05	-	-	-
$2RP_3^-d$	0.52	39	<.001	0.55	22	<.01	0.37	29	<.05	-	-	-
$1RP_3^-$	-	-	-	-0.20	9	NS	-	-	-	0.57	31	<.001
$2RP_4^-m$	0.62	37	<.001	0.52	31	<.01	0.30	31	NS	-	-	-
$2RP_4^-d$	0.63	38	<.001	0.42	31	<.01	0.28	31	NS	-	-	-
$1RP_4^-$	-	-	-	-	-	-	-	-	-	0.65	33	<.001
depth $M_1^-/2RP_3^-m$	0.47	39	.001	0.53	22	<.01	0.47	30	<.01	-	-	-
$2RP_3^-d$	0.49	39	<.001	0.53	22	<.01	0.41	30	<.05	-	-	-
$1RP_3^-$	-	-	-	-0.28	9	NS	-	-	-	0.42	31	<.05
$2RP_4^-m$	0.55	37	<.001	0.52	31	<.01	0.26	32	NS	-	-	-
$2RP_4^-d$	0.58	38	<.001	0.46	31	<.01	0.27	32	NS	-	-	-
$1RP_4^-$	-	-	-	-	-	-	-	-	-	0.56	33	<.001
M_1^-m	0.41	40	<.01	0.33	31	<.05	0.29	34	<.05	0.54	33	<.001
M_1^-d	0.40	40	<.01	0.27	31	NS	0.30	34	<.05	0.45	33	<.01
depth M_2^-/M_2^-m	0.59	40	<.001	0.38	31	<.05	0.45	31	<.01	0.26	33	NS
M_2^-d	0.63	39	<.001	0.42	31	<.01	0.48	28	<.01	0.21	33	NS
depth M_3^-/M_3^-m	0.57	37	<.001	0.32	31	<.05	0.42	20	<.05	-0.06	27	NS
M_3^-d	0.55	32	<.001	0.31	29	NS	0.40	19	<.05	-0.07	27	NS

I (xii) : actual root height/mandibular depth

	Gorilla			Pan			Pongo			H.sapiens		
	r	N	P	r	N	P	r	N	P	r	N	P
depth C_1^-/P_3^- av	0.52	39	<.001	0.58	22	<.01	0.41	29	<.05	-	-	-
P_4^- av	0.64	37	<.001	0.48	31	<.01	0.30	31	NS	-	-	-
depth M_1^-/P_3^- av	0.49	39	<.001	0.54	22	<.01	0.45	30	<.01	-	-	-
P_4^- av	0.58	37	<.001	0.51	31	<.01	0.27	32	NS	-	-	-
M_1^- av	0.42	40	<.01	0.31	31	<.05	0.30	34	<.05	0.51	33	<.01
depth M_2^-/M_2^- av	0.64	39	<.001	0.41	31	<.05	0.48	28	<.01	0.24	33	NS
depth M_3^-/M_3^- av	0.59	32	<.001	0.32	29	<.05	0.42	19	<.05	-0.07	27	NS

I (xiii) : actual root height/palatal dimensions

	Gorilla			Pan			Pongo			H.sapiens		
	r	N	P	r	N	P	r	N	P	r	N	P
palatal length/												
$I\frac{1}{1}$	0.63	29	<.001	0.39	28	<.05	0.42	29	<.05	0.61	25	<.001
$I\frac{2}{2}$	0.62	25	<.001	0.58	24	<.01	0.33	30	<.05	0.68	29	<.001
$3RP\frac{3}{3}$ av	0.51	37	<.001	0.26	27	NS	0.22	24	NS	-	-	-
$1RP\frac{3}{3}$	-	-	-	-	-	-	-	-	-	0.80	26	<.001
$3RP\frac{4}{4}$ av	0.54	38	<.001	0.35	5	NS	0.39	27	<.05	-	-	-
$2RP\frac{4}{4}$ av	-	-	-	0.29	25	NS	-	-	-	-	-	-
$1RP\frac{4}{4}$	-	-	-	-	-	-	-	-	-	0.71	32	<.001
$M\frac{1}{1}$ av	0.37	38	.01	0.50	31	<.01	0.37	32	<.05	0.51	31	<.01
$M\frac{2}{2}$ av	0.47	34	<.01	0.55	30	<.001	0.42	29	<.05	0.69	28	<.001
$M\frac{3}{3}$ av	0.44	35	<.01	0.20	30	NS	0.59	24	.001	0.67	12	<.01
Palatal breadth/												
$I\frac{1}{1}$	0.60	30	<.001	0.15	28	NS	0.46	29	<.01	0.39	25	<.05
$I\frac{2}{2}$	0.59	25	.001	0.26	24	NS	0.35	30	<.05	0.41	29	<.05
$3RP\frac{3}{3}$ av	0.39	38	<.01	0.50	26	<.01	0.30	24	NS	-	-	-
$1RP\frac{3}{3}$	-	-	-	-	-	-	-	-	-	0.60	26	<.001
$3RP\frac{4}{4}$ av	0.47	39	<.01	0.08	5	NS	0.48	27	<.01	-	-	-
$2RP\frac{4}{4}$ av	-	-	-	0.25	24	NS	-	-	-	-	-	-
$1RP\frac{4}{4}$	-	-	-	-	-	-	-	-	-	0.54	32	<.001
$M\frac{1}{1}$ av	0.43	39	<.01	0.38	30	<.05	0.46	32	<.01	0.37	31	<.05
$M\frac{2}{2}$ av	0.43	35	<.01	0.44	29	<.01	0.49	29	<.01	0.56	28	.001
$M\frac{3}{3}$ av	0.44	36	<.01	0.23	29	NS	0.65	24	<.001	0.18	12	NS

I (xiv) : actual root height/palatal index

	Gorilla			Pan			Pongo			H.sapiens		
	r	N	P	r	N	P	r	N	P	r	N	P
$I\underline{1}$	-0.49	29	<.01	-0.35	28	<.05	-0.10	29	NS	-0.40	25	<.05
$I\underline{2}$	-0.50	25	<.01	-0.48	24	<.01	-0.08	30	NS	-0.44	29	<.01
$3RP\underline{3}$ av	-0.44	37	<.01	0.04	26	NS	0.03	24	NS	-	-	-
$1RP\underline{3}$	-	-	-	-	-	-	-	-	-	-0.44	26	<.05
$3RP\underline{4}$ av	-0.43	38	<.01	-0.94	5	<.01	-0.03	27	NS	-	-	-
$2RP\underline{4}$ av	-	-	-	-0.19	24	NS	-	-	-	-	-	-
$1RP\underline{4}$	-	-	-	-	-	-	-	-	-	-0.34	32	<.05
$M\underline{1}$ av	-0.17	38	NS	-0.29	30	NS	0.02	32	NS	-0.29	31	NS
$M\underline{2}$ av	-0.34	34	<.05	-0.31	29	NS	-0.04	29	NS	-0.32	28	NS
$M\underline{3}$ av	-0.30	35	<.05	-0.05	29	NS	-0.18	24	NS	-0.55	12	<.05

Appendix J: Mandibular premolar root form in the fossil hominid sample

J : Fossil hominid mandibular premolar root form

	$P_{\overline{3}}$	$P_{\overline{4}}$
KNM-ER 403	2R:MB+D	2R:M+D
KNM-ER 404	?	?
KNM-ER 725	?2R:MB D	2R:M+D
KNM-ER 726	?2R:M+D	2R:M+D
KNM-ER 727	-	?
KNM-ER 729	-	2R:M+D
KNM-ER 730	2R:MB+D	?2R:M+D
KNM-ER 733	?2R:MB+D	?2R:M+D
KNM-ER 810A	?2R:M+D	2R:M+D
KNM-ER 818	?2R:M+D	?2R:M+D
KNM-ER 819	2T	2R:M+D
KNM-ER 992	2T	1R
KNM-ER 1468	-	2R:M+D
KNM-ER 1482	2T	2R:M+D
KNM-ER 1483	1R	1R
KNM-ER 1501	1R	1R
KNM-ER 1801	2T	2R:M+D
KNM-ER 1802	?2R:M+D	?2R:M+D
KNM-ER 1803	?	?
KNM-ER 1805	?2R:MB+D	?
KNM-ER 1806	2R:M+D	2R:M+D
KNM-ER 1811	?2T	2R:M+D
KNM-ER 1812	?1R	-
KNM-ER 3229	2R:M+D	2R:M+D
KNM-ER 3230	-	2R:M+D
KNM-ER 3729	?2R:MB+D	2R:M+D
KNM-ER 3731	2R:M+D	2R:M+D
KNM-ER 3734	2T	2R:M+D
KNM-ER 3889	?1R	?1R
KNM-ER 3954	2R:M+D	2R:M+D
KNM-ER 5429	-	?
L.H.4	2R:MB+D	2R:M+D
L.H.10	?1R	?1R
L.H.14	1R	?1R

J : Fossil hominid mandibular premolar root form

	$P_{\bar{3}}$	$P_{\bar{4}}$
O.H.7	2T	1R
O.H.13	1R	1R
O.H.16	1R	1R
O.H.22	1R	1R
O.H.23	1R	1R
O.H.37	1R	1R
O.H.51	-	2R:M+D
Peninj	2R:M+D	2R:M+D

Appendix K : The root and crown dimensions and indices in the fossil hominid sample

K (i) : Neck mesiodistal diameter

K (ii) : Location of bifurcation

K (iii) : Actual root height

K (iv) : Projected root height

K (v) : Root mesiodistal diameter

K (vi) : Height of bifurcation

K (vii) : Root angulation

K (viii) : Crown mesiodistal diameter

K (ix) : Crown buccolingual diameter

K (x) : Location of bifurcation index

K (xi) : Root robusticity

K (xii) : Height of bifurcation index

K (xiii) : Root divergence

	I_1^-	I_2^-	C_1^-	P_3^-	P_4^-	M_1^-	M_2^-	M_3^-
KNM-ER 403	-	(5)S	-	(10.1)	(10.1)	(13.0)	(14.2)	-
KNM-ER 404	-	-	-	-	-	-	(15)	(17.4)
KNM-ER 725	-	-	-	-	(11.3)S	(12.5)S	(14.2)S	(14.7)S
KNM-ER 726	-	-	-	-	(12.0)S	-	(14.0)S	(16.9)S
KNM-ER 729 R	(4.1)S	-	(8.0)	-	13.0	14.8	17.1	20.4
KNM-ER 729 I	(4.2)S	-	-	-	13.5	-	16.3	19.7
KNM-ER 730	-	-	(6.7)	-	-	10.3	11.5	11.7
KNM-ER 733	-	-	-	-	-	(13.4)S	-	16.4
KNM-ER 801	-	4.05	-	-	-	-	16.0	16.8
KNM-ER 810	-	-	-	-	(10.7)	(12.5)S	(12.9)S	(14.7)S
KNM-ER 819	-	-	-	-	(8.4)	-	-	-
KNM-ER 820 R	4.3	5.0	-	-	-	11.4	-	-
KNM-ER 820 L	4.2	4.6	-	-	-	11.2	-	-
KNM-ER 992 R	-	-	-	8.9	7.9	11.4	13.0	12.1
KNM-ER 992 L	-	-	-	8.8	7.8	11.8	12.3	11.7
KNM-ER 1468	-	-	-	-	(12.2)S	(15.9)S	(16.7)S	(20.7)S
KNM-ER 1482	-	(3.5)S	-	(8.2)	9.1	(12.0)S	(13.1)	-
KNM-ER 1483	-	(4.7)S	-	(7.4)	(9.3)	-	-	-
KNM-ER 1501	-	-	-	(7.1)	(7.0)	(11.0)	(10.8)	(11.5)
KNM-ER 1502	-	-	-	-	-	12.0	-	-
KNM-ER 1506	-	-	-	-	-	11.7	13.2	-
KNM-ER 1507	-	-	-	-	-	12.1	-	-

	$I_{\bar{1}}$	$I_{\bar{2}}$	$C_{\bar{1}}$	$P_{\bar{3}}$	$P_{\bar{4}}$	$M_{\bar{1}}$	$M_{\bar{2}}$	$M_{\bar{3}}$
KNM-ER 1508	-	-	-	-	-	-	(12.5)S	-
KNM-ER 1801	-	-	-	(6.9)	8.0	(11.9)	-	14.9
KNM-ER 1802 R	-	-	-	8.7	10.6	12.9	15.5	-
KNM-ER 1802 I	-	-	-	-	10.9	13.3	14.9	-
KNM-ER 1803	-	-	-	(7.5)S	(9.5)S	(12)S	-	-
KNM-ER 1806	-	-	-	(9.9)S	(10.6)S	(14.0)S	-	(20.5)S
KNM-ER 1808	-	-	-	-	-	-	-	(13.4)S
KNM-ER 1811	-	-	-	(6.9)S	(8.5)S	-	-	-
KNM-ER 1812	-	(4.0)S	-	-	-	-	-	-
KNM-ER 2597	-	-	-	-	-	-	(11.2)S	-
KNM-ER 3229	-	-	-	(8.2)S	(9.3)S	(12.4)S	-	-
KNM-ER 3230 R	4.3	5.2	7.1	-	12.5	15.0	17.9	18.9
KNM-ER 3230 I	4.3	-	-	10.9	11.6	15.3	17.3	18.7
KNM-ER 3731	-	-	-	(8.2)S	-	-	-	-
KNM-ER 3734	-	-	-	7.8	8.0	11.5	13.0	-
KNM-ER 3954	-	-	-	-	(9.7)	-	-	-
L.H.4 R	-	-	-	10.6	8.4	10.3	12.7	14.2
L.H.4 L	-	-	-	-	7.8	10.9	12.4	-
O.H.7 R	-	-	-	8.5	9.5	12.3	-	-
O.H.7 L	-	-	-	-	9.3	11.9	14.1	-
O.H.13	-	-	-	7.5	7.5	11.0	12.6	13.8
O.H.16 R	-	5.5S	-	-	(7.6)S	-	-	-

	I_1	I_2	C_1	P_3	P_4	M_1	M_2	M_3
O.H.16 L	-	5.5S	-	-	(7.7)S	-	-	-
O.H.22	-	-	-	8.3	7.2	11.3	11.2	(10.6)
O.H.23	-	-	-	-	6.6	11.0	10.9	-
O.H.37	-	-	-	-	(8.5)	11.6	13.7	-
O.H.51	-	-	-	-	8.9	12.0	-	-
Penin] R	-	-	-	9.2	12.4	14.9	15.4	18.2
Penin] I	-	-	-	-	13.4	15.0	16.2	17.1

K (11) : Location of bifurcation

	$P\bar{3}$	$P\bar{4}$	$M\bar{1}$	$M\bar{2}$	$M\bar{3}$
KNM-ER 403	(4.6)	(4.8)	(5.8)	(7.3)	-
KNM-FR 404	-	-	-	-	(8.7)
KNM-ER 728	-	-	-	-	(8.0)
KNM-ER 729 R	-	6.8	7.4	8.4	10.7
KNM-FR 729 I	-	-	-	7.3	9.8
KNM-ER 730	-	-	5.5	5.6	6.8
KNM-ER 733	-	-	-	-	8.4
KNM-FR 801	-	-	-	7.5	7.9
KNM-FR 810	-	(5.1)	-	-	-
KNM-FR 819	-	4.6	-	-	-
KNM-ER 820 R	-	-	5.9	-	-
KNM-ER 820 I	-	-	5.6	-	-
KNM-FR 992 R	-	-	6.1	7.3	6.2
KNM-ER 992 L	-	-	6.5	7.2	-
KNM-FR 1482	-	4.4	-	(6.4)	-
KNM-FR 1501	-	-	(5.1)	(5.8)	(5.9)
KNM-FR 1502	-	-	6.3	-	-
KNM-FR 1506	-	-	-	6.7	-
KNM-ER 1507	-	-	6.2	-	-
KNM-ER 1801	-	3.8	(6.1)	-	8.4
KNM-FR 1802 R	-	-	6.4	7.7	-
KNM-FR 1802 L	-	-	6.5	7.0	-
KNM-ER 3230 R	-	6.8	7.3	8.3	8.4
KNM-ER 3230 L	-	5.6	7.2	8.1	8.7
KNM-ER 3734	-	3.9	6.0	6.4	-
KNM-FR 3954	-	4.4	-	-	-
L.H.4 R	5.1	4.5	5.3	7.0	7.5
L.H.4 L	-	4.6	5.5	6.8	-
O.H.7 R	-	-	5.9	-	-
O.H.7 L	-	-	5.8	6.7	-
O.H.13	-	-	6.0	6.5	6.5
O.H.22	-	-	6.0	6.5	(6.3)
O.H.23	-	-	5.4	5.8	-
O.H.37	-	-	5.6	7.4	-
O.H.51	-	(4.2)	6.4	-	-
Peninj R	4.9	5.9	6.4	7.5	9.1
Peninj L	-	5.4	7.1	7.7	8.6

	$I_{\bar{1}}$	$I_{\bar{2}}$	$C_{\bar{1}}$	$P_{\bar{3}}$ m	$P_{\bar{3}}$ d	$P_{\bar{4}}$ m	$P_{\bar{4}}$ d	$M_{\bar{1}}$ m	$M_{\bar{1}}$ d	$M_{\bar{2}}$ m	$M_{\bar{2}}$ d	$M_{\bar{3}}$ m	$M_{\bar{3}}$ d
KNM-ER 403	-	-	-	(20.1)	(20.8)	(21,1)	(22.5)	(18.4)	(18.2)	(19.6)	(20.1)	-	-
KNM-ER 404	-	-	-	-	-	-	-	-	-	-	-	(21.6)	(21.1)
KNM-ER 728	-	-	-	-	-	-	-	-	-	-	-	(25.0)	-
KNM-ER 729 R	-	-	(32.7)	-	-	23.1	23.4	18.6	17.4	23.5	22.1	20.8	18.2
KNM-ER 729 L	-	-	-	-	-	-	23.3	-	-	22.1	20.9	20.0	19.6
KNM-ER 730	-	-	(21.8)	-	-	-	-	21.4	21.0	24.6	24.1	20.6	19.0
KNM-ER 733	-	-	-	-	-	-	-	-	-	-	-	19.4	18.2
KNM-ER 801	-	18.6S	-	-	-	-	-	-	-	21.0	20.8	21.2	21.0
KNM-ER 810	-	-	-	-	-	(18.4)	(18.9)	-	-	-	-	-	-
KNM-ER 819	-	-	-	-	-	(14.8)	(16.8)	-	-	-	-	-	-
KNM-ER 992 R	-	-	26.6	23.7	23.7	25.5		20.7	21.0	(21.8)	-	-	-
KNM-ER 992 L	-	(20)	25.8	23.2	22.9	25.5		22.1	21.1	(22.2)	-	-	-
KNM-ER 1482	-	-	-	(18.9)	(17.5)	20.7	21.5	-	-	(18.7)	(20.2)	-	-
KNM-ER 1483A	-	-	(22.1)	(17.9)		(17.4)	(16.8)	-	-	-	-	-	-
KNM-ER 1501	-	-	(21.0)	(17.7)		(17.9)		(15.3)	(15.2)	(16.7)	(15.5)	(16.4)	(15.0)
KNM-ER 1502	-	-	-	-	-	-	-	16.5	16.5	-	-	-	-
KNM-ER 1506	-	-	-	-	-	-	-	-	-	16.9	16.0	-	-
KNM-ER 1801	-	-	-	(14.1)	(14.3)	16.1	16.4	(13.5)	(13.5)	-	-	-	15.0
KNM-ER 1802 R	-	-	-	21.0	19.6	22.2	20.9	16.8	15.5	16.7	16.5	-	-
KNM-ER 1802 L	-	-	-	-	-	22.3	21.7	17.5	16.1	16.7	16.4	-	-
KNM-ER 1806	-	-	26.5S	-	-	-	-	-	-	-	-	-	-

K (111) : Actual root height

	$I_{\bar{1}}$	$I_{\bar{2}}$	$C_{\bar{1}}$	$P_{\bar{3}}$ m	$P_{\bar{3}}$ d	$P_{\bar{4}}$ m	$P_{\bar{4}}$ d	$M_{\bar{1}}$ m	$M_{\bar{1}}$ d	$M_{\bar{2}}$ m	$M_{\bar{2}}$ d	$M_{\bar{3}}$ m	$M_{\bar{3}}$ d
KNM-LR 3230R	19.6	21.7	29.6	-	-	25.5	26.7	21.4	21.6	22.1	23.1	(17.5)	-
KNM-LR 3230 L	21.5	-	-	-	25.4	24.7	24.6	22.2	23.9	22.6	21.5	-	-
KNM-ER 3734	-	-	25.4	19.5	19.0	18.4	18.6	16.9	16.4	17.8	18.3	-	-
KNM-ER 3954	-	-	-	-	-	(16.7)	(17.1)	-	-	-	-	-	-
L.H.4 R	-	-	-	16.8	17.1	17.3	16.0	13.8	12.6	13.5	13.3	13.7	-
L.H.4 L	-	-	-	-	-	17.1	16.4	14.2	14.3	14.7	14.5	-	-
O.H.7	-	-	-	20.1	18.9	-	-	-	-	-	-	-	-
O.H.13	-	-	-	18.8		18.6		-	16.4	14.2	13.7	-	-
O.H.16	-	-	(19.0)S	-	-	(16.5)S		14.0S	-	-	-	-	-
O.H.22	-	-	(26.0)	22.9		22.9		19.0	18.5	19.9	18.6	(19.3)	(17.9)
O.H.23	-	-	-	-	-	23.0		17.9	17.9	20.1	19.2	-	-
O.H.37	-	-	(23.8)	-	-	(21.6)		19.6	19.4	18.2	17.8	-	-
O.H.51	-	-	-	-	-	20.7	21.5	21.3	20.5	-	-	-	-
Peninj R	-	-	-	(22.7)	(22.4)	24.6	24.0	19.9	20.5	20.8	19.9	20.5	18.4
Peninj L	-	-	-	-	-	-	23.4	20.4	19.9	19.7	18.9	20.7	19.4

	$I_{\overline{1}}$	$I_{\overline{2}}$	$P_{\overline{3}}$ m	$P_{\overline{3}}$ d	$P_{\overline{4}}$ m	$P_{\overline{4}}$ d	$M_{\overline{1}}$ m	$M_{\overline{1}}$ d	$M_{\overline{2}}$ m	$M_{\overline{2}}$ d	$M_{\overline{3}}$ m	$M_{\overline{3}}$ d
KNM-ER 403	-	-	(20.1)	(20.8)	(20.6)	(22.5)	(18.3)	(18.0)	(19.4)	(19.6)	-	-
KNM-ER 404	-	-	-	-	-	-	-	-	(20)	(20)	(21.6)	(21.1)
KNM-ER 728	-	-	-	-	-	-	-	-	-	(22)	(24.9)	-
KNM-ER 729 R	-	-	-	-	23.0	23.1	18.6	17.2	23.4	21.9	20.6	16.9
KNM-ER 729 L	-	-	-	-	-	23.2	-	-	22.1	20.8	19.8	19.2
KNM-ER 730	-	-	-	-	-	-	20.5	18.9	23.2	22.3	19.1	17.6
KNM-ER 733	-	-	-	-	-	-	-	-	(20.6)	(20.7)	19.4	17.9
KNM-ER 801	-	-	-	-	-	-	-	-	20.8	20.7	21.0	20.8
KNM-ER 810	-	-		-	(18.3)	(18.9)	-	-	-	-	-	-
KNM-ER 819	-	-	-	-	(14.8)	(16.8)	-	-	-	-	-	-
KNM-ER 992R	-	-	23.4	23.5	25.3		20.6	20.9	(21.4)	-	-	-
KNM-ER 9921	-	-	23.0	22.8	(25.2)		21.5	20.6	(21.6)	-	-	-
KNM-ER 1482	-	-	(18.7)	(17.3)	20.7	21.3	-	-	(18.7)	(19.9)	-	-
KNM-ER 1483	-	-	(17.8)		(17.4)	(16.8)	-	-	-	-	-	-
KNM-ER 1501	-	-	(17.7)		(17.8)		(15.3)	(15.0)	(16.4)	(15.0)	(16.3)	(14.4)
KNM-ER 1502	-	-	-	-	-	-	16.2	16.3	-	-	-	-
KNM-ER 1506	-	-	-	-	-	-	-	-	16.6	15.4	-	-
KNM-ER 1508	-	-	-	-	-	-	-	-	18.7s	16.8s	-	-
KNM-ER 1801	-	-	(13.9)	(14.2)	16.1	16.4	(13.4)	(13.2)	-	-	-	14.1
KNM-ER 1802R	-	-	20.9	19.5	22.2	20.9	16.7	15.4	16.1	16.0	-	-
KNM-ER 1802L	-	-	-	-	22.3	21.7	17.4	16.0	16.4	16.2	-	-
KNM-ER 2597	-	-	-	-	-	-	-	-	(16)s	(16)s	-	-

K (iv) : Projected root height

	$I_{\bar{1}}$	$I_{\bar{2}}$	$P_{\bar{3}}$ m	$P_{\bar{3}}$ d	$P_{\bar{4}}$ m	$P_{\bar{4}}$ d	$M_{\bar{1}}$ m	$M_{\bar{1}}$ d	$M_{\bar{2}}$ m	$M_{\bar{2}}$ d	$M_{\bar{3}}$ m	$M_{\bar{3}}$ d
KNM-ER 3230R	19.6	21.4	-	-	25.1	25.7	21.3	21.6	21.9	23.0	(17.5)	-
KNM-ER 3230L	21.5	-	-	25.4	24.5	24.5	22.1	23.9	22.4	21.3	-	-
KNM-ER 3734	-	-	19.3	18.8	18.4	18.5	16.9	16.2	17.6	17.8	-	-
KNM-ER 3954	-	-	-	-	(16.9)	(17.1)	-	-	-	-	-	-
L.H.4 R	-	-	16.8	17.1	17.3	16.0	13.7	12.3	13.1	12.5	13.3	-
L.H.4 L	-	-	-	-	17.1	16.3	14.2	13.2	14.2	13.6	-	-
O.H.7	-	-	19.9	18.9	-	-	-	-	-	-	-	-
O.H.13	-	-	18.6		18.6		-	16.0	14.0	13.6	-	-
O.H.16	-	15.8S	16.0S		(16.5)S		-	-	-	-	-	-
O.H.22	-	-	22.6		22.9		18.8	18.3	19.6	18.2	(19.1)	(17.7)
O.H.23	-	-	-	-	22.9		17.6	17.7	19.3	18.9	-	-
O.H.37	-	-	-	-	(21.6)		18.9	18.9	17.2	16.9	-	-
O.H.51	-	-	-	-	20.7	21.4	20.9	20.2	-	-	-	-
Peninj R	-	-	(22.5)	(22.2)	24.5	23.7	19.9	20.4	20.5	19.3	20.3	17.3
Peninj L	-	-	-	-	-	22.2	20.4	19.8	19.6	18.7	20.5	17.9

R (V) : Root mesiodistal diameter

	$C_{\bar{1}}$	$P_{\bar{3}}$		$P_{\bar{4}}$		$M_{\bar{1}}$		$M_{\bar{2}}$		$M_{\bar{3}}$	
		m	d	m	d	m	d	m	d	m	d
KNM-ER 403	-	(4.0)	(4.2)	(4.5)	(5.1)	(4.5)	(6.0)	(5.2)	(5.6)	-	-
KNM-ER 404	-	-	-	-	-	-	-	-	-	(6.6)	(6.7)
KNM-ER 728	-	-	-	-	-	-	-	-	-	6.7	-
KNM-ER 729R	(6.9)	-	-	5.7	5.8	6.3	5.6	6.8	6.9	8.1	8.4
KNM-ER 729I	-	-	-	-	6.1	-	-	5.9	7.6	6.9	7.0
KNM-ER 730	(5.1)	-	-	-	-	3.9	4.6	4.1	5.5	4.5	5.3
KNM-ER 733	-	-	-	-	-	-	-	-	-	5.5	5.8
KNM-ER 801A	-	-	-	-	-	-	-	6.1	6.6	5.6	7.6
KNM-ER 810	-	-	-	(5.1)	(5.3)	-	-	-	-	-	-
KNM-ER 819	-	-	-	(4.3)	(5.1)	-	-	-	-	-	-
KNM-ER 992R	-	4.9	5.1	5.5		5.6	4.8	(4.8)	-	-	-
KNM-ER 992L	-	4.9	4.9	5.8		5.5	4.6	(5.1)	-	-	-
KNM-ER 1482	-	(4.6)	(4.2)	3.7	3.9	-	-	(5.3)	(5.0)	-	-
KNM-ER 1483	-	(7.5)		(3.8)	(6.0)	-	-	-	-	-	-
KNM-ER 1501	-	(5.7)		(7.0)		(4.0)	(4.2)	(4.3)	(4.2)	(5.2)	(5.8)
KNM-ER 1502	-	-	-	-	-	4.5	4.7	-	-	-	-
KNM-ER 1506	-	-	-	-	-	-	-	4.8	4.9	-	-
KNM-ER 1801	-	(4.0)	(4.0)	3.3	3.7	(4.5)	(4.4)	-	-	-	6.1
KNM-ER 1802R	-	4.6	4.4	5.9	5.6	4.0	4.7	5.3	5.7	-	-
KNM-ER 1802I	-	-	-	5.6	6.0	4.7	5.2	5.0	6.0	-	-
KNM-ER 3230R	6.5	-	-	4.9	6.2	5.2	5.9	6.8	7.3	(6.6)	-
KNM-ER 3230I	-	-	5.5	5.4	5.9	5.7	6.2	6.1	7.8	-	-

K (v) : Root mesiodistal diameter

	$C_{\bar{1}}$	$P_{\bar{3}}$		$P_{\bar{4}}$		$M_{\bar{1}}$		$M_{\bar{2}}$		$M_{\bar{3}}$	
		m	d	m	d	m	d	m	d	m	d
KNM-FR 3734	-	3.5	4.2	4.0	3.6	4.6	4.6	4.8	5.3	-	-
KNM-LR 3954	-	-	-	(4.2)	(4.6)	-	-	-	-	-	-
L.H.4 R	-	3.6	3.9	3.7	3.4	3.8	4.0	4.3	4.4	4.9	-
L.H.4 L	-	-	-	3.4	3.7	4.2	4.0	4.4	4.5	-	-
O.H.7	-	5.6	4.2	-	-	4.7	-	-	-	-	-
O.H.13	-	6.5		5.9		-	4.5	4.7	4.7	-	-
O.H.22	-	6.1		5.2		4.3	4.6	4.9	4.9	(5.0)	(5.0)
O.H.23	-	-	-	6.1		4.2	4.8	4.7	4.9	-	-
O.H.37	-	-	-	8.2		4.5	4.6	5.4	5.8	-	-
O.H.51	-	-	-	3.9	3.8	4.9	5.0	-	-	-	-
Peninj R	-	(3.9)	(4.6)	5.6	5.6	5.1	5.8	6.0	6.6	6.1	6.7
Peninj L	-	-	-	-	6.0	5.5	5.7	6.8	6.2	6.1	7.0

K (vi) : Height of bifurcation

	P_3^-	P_4^-	M_1^-	M_2^-	M_3^-
KNM-ER 403	(5.3)	(5.3)	(4.3)	(4.0)	-
KNM-LP 40'	-	-	-	-	(5.9)
KNM-LR 728	-	-	-	-	(3.8)
KNM-LR 729 R	-	6.8	4.6	6.0	5.5
KNM-LP 729 L	-	-	-	4.9	4.9
KNM-LR 730	-	-	5.4	5.0	5.4
KNM-ER 733	-	-	-	-	6.4
KNM-LR 801	-	-	-	4.0	5.0
KNM-FP 810	-	(5.5)	-	-	-
KNM-LR 819	-	6.4	-	-	-
KNM-ER 829 P	-	-	4.8	-	-
KNM-EP 829 L	-	-	6.2	-	-
KNM-FR 992 R	-	-	6.7	7.0	5.3
KNM-FR 992 L	-	-	7.4	8.1	-
KNM-FR 1482	-	4.7	-	(6.0)	-
KNM-FR 1501	-	-	(3.8)	(4.7)	(4.8)
KNM-FP 1502	-	-	4.8	-	-
KNM-FR 1506	-	-	-	4.1	-
KNM-FR 1507	-	-	4.3	-	-
KNM-LR 1508	-	-	-	(5.5)S	-
KNM-ER 1801	-	5.1	(3.4)	-	5.0
KNM-FR 1802 R	-	-	4.7	4.0	-
KNM-ER 1802 L	-		5.0	4.5	-
KNM-LR 3230 R	-	6.5	5.0	2.6	4.4
KNM-FR 3230 L	-	7.5	6.4	4.2	6.1
KNM-FR 3734	-	(9.8)	3.6	5.2	-
KNM-ER 3954	-	(4.6)	-	-	-
L.H.4 R	5.0	5.0	3.1	2.5	2.5
L.H.4 L	-	5.1	3.6	3.1	-
O.H.7 R	-	-	4.4	-	-
O.H.7 L	-	-	3.5	2.9	-
O.H.13	-	-	4.8	4.0	3.5
O.H.16 R	-	-	3.5S	3.5S	-
O.H.22	-	-	5.3	6.2	(8.2)
O.H.23	-	-	4.1	5.7	-
O.H.37	-	-	4.5	5.1	-
O.H.51	-	(7.8)	4.2	-	-
Penang R	7.5	4.6	4.2	4.9	4.0

	I_1^-	I_2^-	P_3^- m	P_3^- d	P_4^- m	P_4^- d	M_1^- m	M_1^- d	M_2^- m	M_2^- d	M_3^- m	M_3^- d
KNM-ER 403	-	-	(+1)	(-1)	(+11)	((0)	(+2)	(-5)	(-6)	(-11)	-	-
KNM-ER 404	-	-	-	-	-	-	-	-	-	-	(+3)	(-5)
KNM-ER 728	-	-	-	-	-	-	-	-	-	-	(0)	-
KNM-ER 729 U	-	-	-	-	0	-9	+5	-9	-1	-5	-4	-20
KNM-ER 729 L	-	-	-	-	-	-2	-	-	0	-7	-4	-13
KNM-ER 730	-	-	-	-	-	-	-9	-23	-13	-18	-16	-20
KNM-ER 733	-	-	-	-	-	-	-	-	-	-	+1	-8
KNM-ER 801	-	-		-	-	-	-	-	-6	-4	-6	-8
KNM-ER 810	-	-	-	-	(+6)	(-4)	-	-	-	-	-	-
KNM-ER 819	-	-	-	-	(-1)	(0)	-	-	-	-	-	-
KNM-ER 992 P	-	-	-7	-5	-8		0	-11	(-9)	-	-	-
KNM-ER 992 I	-	-	-7	-6	-8		-8	-12	(-10)	-	-	-
KNM-ER 1482	-	-	(-8)	(-8)	+3	-7	-	-	(+2)	(-8)	-	-
KNM-ER 1483	-	-	(-1)		(0)	(-2)	-	-	-	-	-	-
KNM-ER 1501	-	-	(+2)		(0)		(+1)	(-9)	(-8)	(-14)	(-4)	(-18)
KNM-ER 1502	-	-	-	-	-	-	-7	-8	-	-	-	-
KNM-ER 1506	-	-	-	-	-	-	-	-	-8	-15	-	-
KNM-ER 1801	-	-	(-8)	(-6)	+3	-2	(-4)	(-11)	-	-	-	-19
KNM-ER 1802 R	-	-	0	-1	-2	-2	-1	-6	-11	-15	-	-
KNM-ER 1802 I	-	-	-	-	-2	+1	-2	-9	-8	-10	-	-
KNM-ER 3230 P	+2	9	-	-	-	-	-1	-1	-4	-2	(-1)	-
KNM-ER 3230 I	+3	-	-	-1	-	-	-2	-3	-7	-7	-	-

K (v11) : Root angulation

	$I_{\overline{1}}$	$I_{\overline{2}}$	$P_{\overline{3}}$ m	$P_{\overline{3}}$ d	$P_{\overline{4}}$ m	$P_{\overline{4}}$ d	$M_{\overline{1}}$ m	$M_{\overline{1}}$ d	$M_{\overline{2}}$ m	$M_{\overline{2}}$ d	$M_{\overline{3}}$ m	$M_{\overline{3}}$ d
KNM-ER 3734	-	-	-5	-9	0	-3	+1	-9	-7	-14	-	-
KNM-ER 3954	-	-	-	-	(+2)	(-1)	-	-	-	-	-	-
I.H.4 R	-	-	+1	-3	+2	-5	7	-15	-10	-19	-11	-
L.H.4 I	-	-	-	-	0	-4	-1	-20	-10	-16	-	-
O.H.7	-	-	-8	-7	-	-	-5	-	-	-	-	-
O.H.13	-	-	-2		0		-	-12	-6	-9	-	-
O.H.22	-	-	-8		-3		-6	-8	-8	-11	(-7)	(-9)
O.H.23	-	-	-	-	-5		-6	-8	-12	-12	-	-
O.H.37	-	-	-	-	(-1)		-11	-11	-14	-17	-	-
O.H.51	-	-	-	-	+3	-5	-8	-8	-	-	-	-
Peninj P	-	-	(-3)	(-6)	-1	-12	+3	-5	-8	-10	-6	-20
Peninj I	-	-	-	-	-	-	+2	-8	-1	-7	-3	-23

	P_1	P_2	C_1	P_3	P_4	M_1	M_2	M_3
KNM-ER 403	-	-	-	-	(12.0)	(15)	(15)	-
KNM-ER 404	-	-	-	-	-	-	(18.5)	-
KNM-ER 725	-	-	-	-	(12.2)	(14)	(16)	(16.2)
KNM-ER 729 R	(5.0)	-	-	-	(13.4)	(17)	(20)	(20.5)
KNM-ER 729 L	(4.5)	-	8.6	12.1	15.0	-	20.0	21.2
KNM-ER 730	-	-	-	-	-	(12.6)	(13.0)	13.6
KNM-ER 733	-	-	-	-	-	-	-	(19.0)
KNM-ER 801	-	6.1	-	-	-	-	19.0	(19.2)
KNM-ER 810B	-	-	-	-	-	-	-	17.7
KNM-ER 818	-	-	-	-	14.9	(17.8)	(20.3)	-
KNM-ER 820R	6.2	7.3	-	-	-	12.5	-	-
KNM-ER 820L	6.1	7.3	-	-	-	12.5	-	-
KNM-ER 992R	-	-	8.9	9.5	8.6	12.5	13.6	13.2
KNM-FR 992L	-	7.2	9.1	9.7	8.8	12.6	13.0	13.4
KNM-ER 1482	-	-	-	-	10.3	(13.2)	(15)	-
KNM-ER 1502	-	-	-	-	-	13.7	-	-
KNM-ER 1506	-	-	-	-	-	13.7	14.3	-
KNM-ER 1507	-	-	-	-	-	13.2	-	-
KNM-ER 1508	-	-	-	-	-	-	14.0	-

K(viii) : Crown mesiodistal diameter

	I_1^-	I_2^-	C_1^-	P_3^-	P_4^-	M_1^-	M_2^-	M_3^-
KNM-ER 1801	-	-	-	-	9.8	(13.9)	-	(16.8)
KNM-ER 1802 R	-	-	-	10.7	11.4	14.8	16.6	-
KNM-ER 1802 L	-	-	-	-	12.1	14.8	17.0	-
KNM-ER 1805	-	-	-	-	-	-	14.3	14.6
KNM-ER 2597	-	-	-	-	-	-	(15.6)	-
KNM-ER 3229 D	-	-	-	-	13.0	-	-	-
KNM-ER 3229 E	-	-	-	-	12.8	-	-	-
KNM-ER 3230 R	5.6	6.4	7.8	11.0	14.5	17.0	20.8	21.3
KNM-ER 3230 L	5.3	6.6	7.5	11.4	13.8	-	(20.0)	20.5
KNM-ER 3734	-	-	8.2	8.9	9.1	13.6	14.1	-
L.H.4 R	-	-	-	11.4	10.0	12.6	15.0	16.7
L.H.4 L	-	-	-	-	10.1	13.0	15.1	-
L.H.14	-	-	9.9	10.5	11.5	-	-	-
O.H.7 R	6.4	7.1	8.9	9.7	10.6	14.3	-	-
O.H.7 L	6.5	7.3	8.9	9.5	10.4	14.1	15.7	-
O.H.13	-	-	7.6	9.0	9.0	13.0	14.2	14.8
O.H.16 R	-	7.6	(9.6)	10.6	10.2	14.6	15.4	15.9
O.H.16 L	6.4	7.7	-	-	10.1	-	-	15.9
O.H.22	-	-	-	10.1	9.0	13.4	13.0	-
O.H.37	-	-	-	-	-	13.0	14.7	-

K(viii) : Crown mesiodistal diameter

	$I_{\bar{1}}$	$I_{\bar{2}}$	$C_{\bar{1}}$	$P_{\bar{3}}$	$P_{\bar{4}}$	$M_{\bar{1}}$	$M_{\bar{2}}$	$M_{\bar{3}}$
O.H.51	-	-	-	-	-	14.0	-	-
Peninj R	5.6	6.6	(7.7)	10.1	13.2	16.4	17.6	18.8
Peninj L	5.6	6.2	7.3	-	14.6	16.6	17.8	18.2

	$I_{\bar{1}}$	$I_{\bar{2}}$	$C_{\bar{1}}$	$P_{\bar{3}}$	$P_{\bar{4}}$	$M_{\bar{1}}$	$M_{\bar{2}}$	$M_{\bar{3}}$
KNM-ER 729 R	8.0	-	9.7	-	16.3	-	18.1	19.0
KNM-ER 729 L	8.0	-	9.7	13.6	14.6	16.0	(18.0)	19.0
KNM-ER 730	-	-	-	-	-	(11.5)	(11.6)	11.5
KNM-ER 801	-	6.7	-	-	-	-	16.7	(16.0)
KNM-ER 810B	-	-	-	-	-	-	-	15.6
KNM-ER 818	-	-	-	-	15.9	-	(18.4)	-
KNM-ER 820 R	6.3	6.7	-	-	-	10.7	-	-
KNM-ER 820 L	6.3	6.9	-	-	-	(10.6)	-	-
KNM-ER 992 R	-	-	9.5	10.5	11.0	10.9	12.3	12.1
KNM-ER 992 L	-	7.0	-	10.3	10.9	10.9	12.2	12.3
KNM-ER 1502	-	-	-	-	-	11.5	-	-
KNM-ER 1506	-	-	-	-	-	12.7	13.3	-
KNM-ER 1507	-	-	-	-	-	11.1	-	-
KNM-ER 1508	-	-	-	-	-	-	(12.3)	-
KNM-ER 1801	-	-	-	-	-	(13.2)	-	(14.9)
KNM-ER 1802 R	-	-	-	11.5	12.0	13.0	14.2	-
KNM-ER 1802 L	-	-	-	-	11.8	13.2	14.2	-
KNM-ER 1805	-	-	-	-	-	-	12.9	12.2
KNM-ER 2597	-	-	-	-	-	-	14.0	-
KNM-ER 3229 D	-	-	-	-	13.2	-	-	-

K(ix) : Crown buccolingual diameter

	$I_{\bar{1}}$	$I_{\bar{2}}$	$C_{\bar{1}}$	$P_{\bar{3}}$	$P_{\bar{4}}$	$M_{\bar{1}}$	$M_{\bar{2}}$	$M_{\bar{3}}$
KNM-ER 3229 E	-	-	-	-	14.1	-	-	-
KNM-ER 3230 R	6.4	8.1	9.2	13.4	16.5	15.4	18.6	16.9
KNM-ER 3230 L	6.5	-	9.5	13.9	-	-	(19.0)	16.5
KNM-ER 3734	-	-	-	8.0	8.1	10.6	11.7	-
L.H.4 R	-	-	-	10.1	10.7	12.4	-	13.9
L.H.4 L	-	-	-	-	11.0	(12.3)	13.7	-
L.H.14	-	-	10.2	12.5	11.1	-	-	-
O.H.7 R	6.6	7.5	-	9.8	10.7	12.6	-	-
O.H.7 L	6.7	7.6	-	9.7	10.7	12.5	13.7	-
O.H.13	-	-	7.9	8.7	9.9	11.6	12.0	12.4
O.H.16 R	-	7.6	10.0	11.1	10.9	12.8	15.1	14.4
O.H.16 L	7.0	7.5	-	-	11.0	-	-	14.3
O.H.22	-	-	-	9.2	10.0	12.0	11.7	-
O.H.37	-	-	-	-	-	10.8	13.3	-
O.H.51	-	-	-	-	-	12.9	-	-
Peninj R	6.2	6.5	8.6	13.4	14.9	15.5	16.2	15.7
Peninj L	6.3	6.4	8.2	13.1	15.0	15.4	16.2	16.1

K (x) : Location of bifurcation index

	$P\bar{3}$	$P\bar{4}$	$M\bar{1}$	$M\bar{2}$	$M\bar{3}$
KNM-ER 403	(45.6)	(47.5)	(44.6)	(51.4)	-
KNM-ER 404	-	-	-	-	(50.0)
KNM-ER 729 R	-	52.3	50.0	49.1	52.5
KNM-ER 729 L	-	-	-	44.8	49.8
KNM-ER 730	-	-	53.4	48.7	58.1
KNM-ER 733	-	-	-	-	51.2
KNM-ER 801	-	-	-	46.9	47.0
KNM-ER 810	-	(47.7)	-	-	-
KNM-ER 819	-	(54.8)	-	-	-
KNM-ER 820 R	-	-	51.8	-	-
KNM-ER 820 I	-	-	50.0	-	-
KNM-ER 992 R	-	-	53.5	56.2	51.2
KNM-ER 992 I	-	-	55.1	58.5	-
KNM-ER 1482	-	48.4	-	(48.9)	-
KNM-ER 1501	-	-	(46.4)	(53.7)	(51.3)
KNM-ER 1502	-	-	52.5	-	-
KNM-ER 1506	-	-	-	50.8	-
KNM-ER 1507	-	-	51.2	-	-
KNM-ER 1801	-	47.5	(51.?)	-	56.4
KNM-ER 1802 R	-	-	49.6	49.7	-
KNM-ER 1802 I	-	-	48.9	47.0	-
KNM-ER 3230 R	-	54.4	48.7	46.4	44.4
KNM-ER 3230 L	-	48.3	47.1	46.8	46.5
KNM-ER 3734	-	48.8	52.2	49.2	-
KNM-ER 3954	-	(45.4)	-	-	-
L.H.4 R	48.1	53.6	51.5	55.1	52.8
L.H.4 I	-	59.0	50.5	54.3	-
O.H.7 R	-	-	48.0	-	-
O.H.7 L	-	-	48.7	47.5	-
O.H.13	-	-	54.6	51.6	47.1
O.H.22	-	-	53.1	58.0	(59.4)
O.H.23	-	-	49.1	53.2	-
O.H.37	-	-	48.3	54.0	-
O.H.51	-	(47.2)	53.3	-	-
Peninj R	53.3	47.6	43.0	48.7	50.0
Peninj L	-	40.3	47.3	47.5	50.3

	$C_{\overline{1}}$	$P_{\overline{3}}$		$P_{\overline{4}}$		$M_{\overline{1}}$		$M_{\overline{2}}$		$M_{\overline{3}}$	
		m	d	m	d	m	d	m	d	m	d
KNM-ER 403	-	(19.9)	(20.2)	(21.3)	(22.7)	(24.5)	(33.0)	(26.5)	(27.9)	-	-
KNM-ER 404	-	-	-	-	-	-	-	-	-	(30.6)	(31.8)
KNM-ER 728	-	-	-	-	-	-	-	-	-	(26.8)	-
KNM-ER 729 R	(21.1)	-	-	24.5	24.8	33.9	32.2	28.9	31.2	38.9	46.2
KNM-ER 729 I	-	-	-	-	26.2	-	-	26.7	36.4	34.5	35.7
KNM-ER 730	(23.4)	-	-	-	-	18.2	21.9	16.7	22.8	21.9	27.9
KNM-ER 733	-	-	-	-	-	-	-	-	-	28.4	31.9
KNM-ER 801	-	-	-	-	-	-	-	29.1	31.7	26.4	36.2
KNM-ER 810	-	-	-	(27.7)	(28.0)	-	-	-	-	-	-
KNM-ER 819	-	-	-	(29.1)	(30.4)	-	-	-	-	-	-
KNM-ER 992 R	-	20.7	21.5	21.6		27.1	22.9	(22.0)	-	-	-
KNM-ER 992 L	-	21.1	21.4	22.8		24.9	21.8	(23.0)	-	-	-
KNM-ER 1482	-	(24.3)	(24.0)	17.9	18.1	-	-	(28.3)	(24.8)	-	-
KNM-ER 1483	-	(41.9)		(21.8)	(35.7)	-	-	-	-	-	-
KNM-ER 1501	-	(38.2)		(39.1)		(26.1)	(27.0)	(25.8)	(27.1)	(31.7)	(38.7)
KNM-ER 1502	-	-	-	-	-	27.3	28.5	-	-	-	-
KNM-ER 1506	-	-	-	-	-	-	-	28.4	30.6	-	-
KNM-ER 1801	-	(28.4)	(28.0)	20.5	22.6	(33.3)	(32.6)	-	-	-	40.7
KNM-ER 1802 P	-	21.9	22.5	26.6	26.8	23.8	30.3	31.7	34.6	-	-
KNM-ER 1802 I	-	-	-	25.1	27.7	26.9	32.3	29.9	36.6	-	-

A (XI) : Root robusticity

	$C_{\overline{I}}$	$P_{\overline{3}}$		$P_{\overline{4}}$		$M_{\overline{I}}$		$M_{\overline{2}}$		$M_{\overline{3}}$	
		m	d	m	d	m	d	m	d	m	d
KNM-ER 3230 R	22.0	-	-	19.2	23.2	24.3	27.3	30.8	31.6	(37.7)	-
KNM-ER 3230 I	-	-	21.7	21.9	24.0	25.7	25.9	27.0	36.3	-	-
KNM-ER 3734	-	18.0	22.1	21.7	19.4	27.2	28.1	27.0	29.0	-	-
KNM-ER 3954	-	-	-	(25.2)	(26.9)	-	-	-	-	-	-
L.H.4 P	-	21.4	22.9	21.4	21.3	27.5	31.8	31.9	33.1	35.8	-
L.H.4 I	-	-	-	19.9	22.6	29.6	30.0	29.9	31.0	-	-
O.H.7	-	27.9	22.2	-	-	-	-	-	-	-	-
O.H.13	-	34.6		31.7		-	27.4	33.1	34.3	-	-
O.H.22	-	26.6		22.7		22.6	24.9	24.6	26.3	(25.9)	(27.9)
O.H.23	-	-	-	26.5		22.1	26.8	23.4	25.5	-	-
O.H.37	-	-	-	(38.0)		23.0	23.7	29.7	32.6	-	-
O.H.51	-	-	-	18.3	17.7	23.0	24.4	-	-	-	-
Penang P	-	(17.2)	(20.5)	22.8	23.3	25.6	28.3	28.9	33.2	29.8	36.4
Penang I	-	-	-	-	25.6	27.0	28.6	34.5	33.8	29.5	36.1

F (xii) : Height of bifurcation index

	$P\frac{}{3}$	$P\frac{}{4}$	$M\frac{}{1}$	$M\frac{}{2}$	$M\frac{}{3}$
KNM-ER 403	(25.5)	(23.0)	(23.5)	(20.4)	-
KNM-ER 404	-	-	-	-	(27.3)
KNM-ER 728	-	-	-	-	(15.3)
KNM-ER 729 P	-	29.4	24.7	25.6	26.7
KNM-ER 729 L	-	-	-	22.2	24.8
KNM-ER 730	-	-	26.3	21.6	28.3
KNM-ER 733	-	-	-	-	33.0
KNM-ER 801	-	-	-	19.2	23.8
KNM-ER 810	-	(29.1)	-	-	-
KNM-ER 819	-	(38.1)	-	-	-
KNM-ER 992 R	-	-	32.1	-	-
KNM-ER 992 L	-	-	24.4	-	-
KNM-ER 1482	-	29.1	-	(30.2)	-
KNM-ER 1501	-	-	(24.8)	(28.7)	(29.5)
KNM-ER 1502	-	--	29.5	-	-
KNM-ER 1506	-	-	-	24.7	-
KNM-ER 1508	-	-	-	29.45	-
KNM-ER 1801	-	31.1	(25.4)	-	-
KNM-ER 1802 P	-	-	28.1	24.9	-
KNM-ER 1802 I	-	-	28.7	27.4	-
KNM-ER 3230 P	-	25.3	29.2	11.3	(25.1)
KNM-ER 3230 L	-	30.6	26.8	18.8	-
KNM-ER 3734	-	(53.0)	21.3	29.2	-
KNM-ER 3954	-	(26.9)	-	-	-
L.H.4 R	29.2	28.9	22.6	19.1	18.9
L.H.4 I	-	29.8	25.4	21.8	-
O.H.13	-	-	-	28.6	-
O.H.22	-	-	28.2	21.6	(42.9)
O.H.23	-	-	23.3	29.7	-
O.H.37	-	-	23.8	29.7	-
O.H.51	-	(36.5)	20.1	-	-
Penang P	33.3	18.8	20.6	23.9	19.7
Penang L	-	-	27.9	31.1	19.5

K (xiii) : Foot divergence

	P_3	P_4	M_1	M_2	M_3
KN -LR 402	(2)	(11)	(+7)	(5)	-
KNM-EP 404	-	-	-	-	(+8)
KNM-ER 729 R	-	+9	+14	+4	+16
KNM-EP 729 I	-	-	-	+7	+9
KNM-ER 730	-	-	-14	-	4
KNM-EP 732	-	-	-	-	+9
KNM-ER 801	-	-	-	-2	+2
KNM-ER 810	-	(+10)	-	-	-
KNM-EP 819	-	(-1)	-	-	-
KNM-ER 992 R	-2	-	+11	-	-
KNM-EP 992 L	-1	-	+4	-	-
KNM-ER 1482	(0)	+10	-	+10	-
KNM-EP 1483	-	-2	-	-	-
KNM-EP 1501	-	-	+9	+6	+14
KNM-ER 1502	-	-	+1	-	-
KNM-EP 1506	-	-	-	7	-
KNM-EP 1801	(12)	-5	+7	-	-
KNM-ER 1802 R	+1	0	-7	+4	-
KNM-EP 1802 I	-	-3	+7	+2	-
KNM-ER 3230 R	-	-	0	-2	-
KNM-ER 3230 I	-	-	0	0	-
KNM-EP 3734	+4	+3	+10	7	-
KNM-ER 3954	-	+3	-	-	-
I.H.4 R	+4	7	+22	+9	-
I.H.4 I	-	+4	+19	+6	-
O.H.7	-1	-	-	-	-
O.H.13	-	-	-	+3	-
O.H.22	-	-	-2	-3	+2
O.H.23	-	-	+2	0	-
O.H.37	-	-	0	+3	-
O.H.51	-	+8	0	-	-
Penang R	3	-11	+8	+2	+14
Penang I	-	-	+10	+6	+20

Appendix L : Published root dimensions for early fossil hominids

L (i) : Neck mesiodistal diameter

L (ii) : Root height

L (iii) : Root mesiodistal diameter

L(i): Neck mesiodistal diameter

Specimen		Reference
$I_{\overline{1}}$		
L.H.14	4.3	White, 1977
Sts 7	3.9	Robinson, 1956
Sts 24	3.7	Robinson, 1956
KNM-ER 403	(4.0)	Leakey et al, 1971
$I_{\overline{2}}$ KNM-ER 1802	4.3	Day et al, 1976
L.H.14	4.0	White, 1977
Sts 7	3.9	Robinson, 1956
KNM-ER 403	4.6	Leakey et al, 1971
KNM-ER 1483A	5.8	Leakey & Wood, 1974a
KNM-ER 1802	4.0	Day et al, 1976
$C_{\overline{1}}$		
BMNH M 18773	7.2	White, 1980
L.H.4	7.3	White, 1977
L.H.14	7.2	White, 1977
KNM-ER 403	7.6	Leakey et al, 1971
KNM-ER 730 R	5.1	Day & Leakey, 1973
KNM-ER 730 L	5.5	Day & Leakey, 1973
KNM-ER 810A	(5.0)	Leakey & Walker, 1973
KNM-ER 818	(8.0)	Leakey & Walker, 1973
KNM-ER 1483A	7.7	Leakey & Wood, 1974a
KNM-ER 1501	5.6	Leakey & Wood, 1974a
KNM-ER 1801	4.2	Day et al, 1976
KNM-ER 1802	7.2	Day et al, 1976
KNM-ER 1806	(7.4)	Day et al, 1976
KNM-ER 1812	5.5	Day et al, 1976
Atlanthropus I	7.7	Arambourg & Hoffstetter, 1963
Atlanthropus II	7.5	Arambourg & Hoffstetter, 1963
$P_{\overline{3}}$		
KNM-ER 1483A	7.0	Leakey & Wood, 1974a
KNM-ER 1501	5.3	Leakey & Wood, 1974a
KNM-ER 1801	3.8	Day et al, 1976
KNM-ER 1803	8.1	Day et al, 1976
KNM-ER 1811	4.5	Day et al, 1976

L(i): Neck mesiodistal diameter

Specimen		Reference
P_4		
KNM-ER 1468	12.0	Day et al, 1976
KNM-ER 1483A	7.7	Leakey & Wood, 1974a
KNM-ER 1501	6.0	Leakey & Wood, 1974a
KNM-ER 1803	9.5	Day et al, 1976
KNM-ER 1806	10.4	Day et al, 1976
M_1		
KNM-ER 1468	15.4	Day et al, 1976
KNM-ER 1483A	11.3	Leakey & Wood, 1974a
KNM-ER 1501	11.0	Leakey & Wood, 1974a
KNM-ER 1803	(11.5)	Day et al, 1976
KNM-ER 1806	(13)	Day et al, 1976
M_1		
KNM-ER 1468	16.3	Day et al, 1976
KNM-ER 1501	11.7	Leakey & Wood, 1974a
KNM-ER 1806	(14)	Day et al, 1976
M_3		
KNM-ER 1468	20.8	Day et al, 1976
KNM-ER 1501	12.6	Leakey & Wood, 1974a
KNM-ER 1806	19	Day et al, 1976
I_1		
KNM-ER 1590	8.8	Day et al, 1976
I_2		
L.H.5	4.2	White, 1977
KNM-ER 1805	5.0	Day et al, 1976
C^1		
L.H.5	7.1	White, 1977
TM 1517	7.0	Robinson, 1956
KNM-ER 733	(6.0)	Leakey & Walker, 1973
Telanthropus III	7.3	Robinson, 1953

L(ii): Root height

Specimen			Reference
$I_{\overline{1}}$			
L.H.14		(18)	White, 1977
Atlanthropus		12.2	Arambourg & Hoffstetter, 1963
Sinanthropus no.57		18.0	Weidenreich, 1937
Sinanthropus no.58		18.0	Weidenreich, 1937
$I_{\overline{2}}$			
L.H.14		(16.6)	White, 1977
Atlanthropus		15.0	Arambourg & Hoffstetter, 1963
Sinanthropus no.11		18.0	Weidenreich, 1937
Sinanthropus no.62		19.0	Weidenreich, 1937
Sinanthropus no.63		19.0	Weidenreich, 1937
Sinanthropus no.66		19.4	Weidenreich, 1937
$C_{\overline{1}}$			
L.H.4		(25)	White, 1977
L.H.14		23.5	White, 1977
TM 1528		(21.0)	Robinson, 1956
Sts 3		24.6	Robinson, 1956
SK 29		19.0	Robinson, 1956
SK 94		(23.0)	Robinson, 1956
KNM-ER 1801		>19	Day et al, 1976
KNM-ER 1806		>27	Day et al, 1976
Meganthropus 1949		< 20	Weidenreich, 1945
Sinanthropus no.17		24.2	Weidenreich, 1937
Sinanthropus no.72		26.2	Weidenreich, 1937
Sinanthropus no.74		21.0	Weidenreich, 1937
$P_{\overline{3}}$			
L.H.14		17.5	White, 1980
Omo 75i-1255		21.6	Coppens, 1973b
A.robustus Kr	$\overline{X}$m	18.0	Sperber, 1974
	$\overline{X}$d	17.0	Sperber, 1974
A.robustus SK	$\overline{X}$m	16.8	Sperber, 1974
	$\overline{X}$d	17.6	Sperber, 1974
Homo sp. SK	1R	13.2	Sperber, 1974
Telanthropus		13.9	Robinson, 1953
Sinanthropus no.21		15.1	Weidenreich, 1937
Sinanthropus no.23		15.7	Weidenreich, 1937
Sinanthropus no.24		14.4	Weidenreich, 1937
Sinanthropus no.82		18.1/19.1	Weidenreich, 1937

L(ii): Root height

Specimen			Reference
$P_{\overline{3}}$ (cont.)			
Sinanthropus no.83		18.8	Weidenreich, 1937
Sinanthropus no.85		17.0	Weidenreich, 1937
Sinanthropus no.103'		16.8	Weidenreich, 1937
Sinanthropus no.132'		18.8	Weidenreich, 1937
$P_{\overline{4}}$			
A.africanus Sts	$\bar{X}$m	12.0	Sperber, 1974
	$\bar{X}$d	13.3	Sperber, 1974
A.robustus SK	$\bar{X}$m	16.8	Sperber, 1974
	$\bar{X}$d	15.7	Sperber, 1974
Sinanthropus no.91		19.2	Weidenreich, 1937
Sinanthropus no.93		17.3	Weidenreich, 1937
Chang-yang		20.5	Chang, 1962
$M_{\overline{1}}$			
L.H.16 d		14.2	White, 1980
A.robustus SK	$\bar{X}$m	18.0	Sperber, 1974
	$\bar{X}$d	17.0	Sperber, 1974
Sinanthropus no.35	m	14.7	Weidenreich, 1937
	d	14.7	Weidenreich, 1937
Sinanthropus no.38	m	13.1	Weidenreich, 1937
	d	14.2	Weidenreich, 1937
Sinanthropus no.102	m	16.1	Weidenreich, 1937
	d	15.5	Weidenreich, 1937
Sinanthropus no.147	'd	18.5	Weidenreich, 1937
$M_{\overline{2}}$			
Omo L44-2466	m	18.1	Coppens, 1973a
	d	18.1	Coppens, 1973a
A.robustus Kr	$\bar{X}$m	19.5	Sperber, 1974
	$\bar{X}$d	20.0	Sperber, 1974
A.robustus SK	$\bar{X}$m	16.7	Sperber, 1974
	$\bar{X}$d	17.4	Sperber, 1974
KNM-ER 1803		>22	Day et al, 1976
Sinanthropus no.45		15.5	Weidenreich, 1937
Sinanthropus no.138'	d	16.0	Weidenreich, 1937

L(ii): Root height

Specimen			Reference
$M\frac{-}{3}$			
L.H.4 d		11.4	White, 1977
L.H.13 m		(14)	White, 1977
L.H.15 m		12.2	White, 1980
A.africanus Sts	$\bar{X}m$	16.0	Sperber, 1974
	$\bar{X}d$	14.2	Sperber, 1974
A.robustus Kr	$\bar{X}m$	19.2	Sperber, 1974
	$\bar{X}d$	13.5	Sperber, 1974
A.robustus SK	$\bar{X}m$	17.3	Sperber, 1974
	$\bar{X}d$	15.5	Sperber, 1974
Sinanthropus no.114		11.6	Weidenreich, 1937
Sinanthropus no.116		15.5	Weidenreich, 1937
Sinanthropus no.134'		13.0	Weidenreich, 1937
Sinanthropus no.136'		13.6	Weidenreich, 1937
I^1			
SK 2		(19)	Robinson, 1956
O.H.5		(20)	Tobias, 1967
Sinanthropus no.2		18.3	Weidenreich, 1937
Sinanthropus no.3		18.0	Weidenreich, 1937
Sinanthropus no.4		11.5	Weidenreich, 1937
Sinanthropus no.53		20.7	Weidenreich, 1937
Tingts'un		11.0	Chang, 1962
I^2			
L.H.5		14.8	White, 1977
SK 3		20	Robinson, 1956
SK 70		17.5	Robinson, 1956
O.H. 29		>20	Rightmire, 1980
Sinanthropus no.141'		19.0	Weidenreich, 1937
C^1			
L.H.5		20.6	White, 1977
TM 1527		22.6	Robinson, 1956
Sts 48		21.3	Robinson, 1956
SK 4		26.6	Robinson, 1956
KNM-ER 1804		26	Day et al, 1976
Telanthropus III		19.8	Robinson, 1953
Sangiran 15		21.2	Jacob, 1972

L(i1): Root height

Specimen			Reference
$C^{\underline{1}}$ (cont.)			
Sinanthropus no.14		23.2	Weidenreich,1937
Sinanthropus no.15		21.8	Weidenreich, 1937
Sinanthropus no.67		22.8	Weidenreich,1937
Sinanthropus no.68		22.4	Weidenreich,1937
$P^{\underline{3}}$			
L.H.5 b		(13)	White,1977
L.H.25 1		11.8	White,1980
A.africanus Sts	$\bar{X}$mb	13.5	Sperber,1974
	$\bar{X}$db	14.0	Sperber,1974
	$\bar{X}$l	13.7	Sperber,1974
A.robustus SK	$\bar{X}$mb	16.8	Sperber,1974
	$\bar{X}$db	16.8	Sperber,1974
	$\bar{X}$l	15.9	Sperber,1974
KNM-ER 1804	1	23	Day et al,1976
Sinanthropus no.77		20.4	Weidenreich,1937
Sinanthropus no.78		20.0	Weidenreich,1937
$P^{\underline{4}}$			
L.H.5 b		(12)	White,1977
L.H.22 1		(15)	White,1980
mb		16.1	White,1980
db		15.5	White,1980
A.africanus Sts	$\bar{X}$mb	16.5	Sperber,1974
A.robustus SK	$\bar{X}$mb	17.2	Sperber,1974
	$\bar{X}$db	16.2	Sperber,1974
	$\bar{X}$l	17.8	Sperber,1974
KNM-ER 1804		23	Day et al,1976
Sinanthropus no.28		13.3	Weidenreich,1937
Sinanthropus no.87		16.0	Weidenreich,1937
Sinanthropus no.88		16.2	Weidenreich,1937
$M^{\underline{1}}$			
L.H.5 db		(10)	White,1977
Omo B-23b b		10.8	Howell,1969b
A.africanus Sts	$\bar{X}$l	13.2	Sperber,1974
A.robustus SK	$\bar{X}$mb	15.6	Sperber,1974
	$\bar{X}$db	14.9	Sperber,1974
	$\bar{X}$l	14.9	Sperber,1974

L(ii): Root height

Specimen			Reference
M^1 (cont.)			
Sinanthropus no.33		15.4	Weidenreich,1937
Sinanthropus no.94 b		15.4	Weidenreich,1937
Sinanthropus no.95 1		13.7	Weidenreich,1937
Sinanthropus no.144'mb		12.7	Weidenreich,1937
	db	13.0	Weidenreich,1937
	1	14.2	Weidenreich,1937
M^2			
L.H.5 db		10.9	White,1980
A.africanus Sts	$\bar{X}$mb	14.2	Sperber,1974
	$\bar{X}$db	13.2	Sperber,1974
	$\bar{X}$1	12.5	Sperber,1974
KNM-ER 1804 1		22	Day et al,1976
db		19	Day et al,1976
Trinil 1		12	Dubois,1924
b		13	Dubois,1924
Sinanthropus no.39 1		15.2	Weidenreich,1937
Sinanthropus no.42 b		17.7	Weidenreich,1937
Sinanthropus no.104 1		15.1	Weidenreich,1937
Sinanthropus no.105		13.5	Weidenreich,1937
Sinanthropus no.145' b		13.0	Weidenreich,1937
	1	14.2	Weidenreich,1937
M^3			
L.H.8 1		13.0	White,1977
db		12.0	White,1977
A.africanus MLD	$\bar{X}$mb	12.6	Sperber,1974
	$\bar{X}$db	12.3	Sperber,1974
A.africanus Sts	$\bar{X}$mb	12.7	Sperber,1974
	$\bar{X}$db	11.5	Sperber,1974
	$\bar{X}$1	13.7	Sperber,1974
A.robustus SK	$\bar{X}$mb	16.7	Sperber,1974
	$\bar{X}$db	16.7	Sperber,1974
	$\bar{X}$1	16.2	Sperber,1974
Homo sp. SK	db	15.5	Sperber,1974
Trinil 1		12.5	Dubois,1924
b		14	Dubois,1924

L(ii): Root height

Specimen			Reference
M^3 (cont.)			
Sinanthropus no.46	mb	14.5	Weidenreich, 1937
	db	12.5	Weidenreich, 1937
	l	16.5	Weidenreich, 1937
Sinanthropus no.49	l	10.3	Weidenreich, 1937
Sinanthropus no.112	l	16.3	Weidenreich, 1937
	b	15.0	Weidenreich, 1937
Sinanthropus no.113	l	16.3	Weidenreich, 1937
	b	15.0	Weidenreich, 1937
Sinanthropus no.146'	l	14.2	Weidenreich, 1937
	b	13.0	Weidenreich, 1937

L(iii):Root mesiodistal diameter

Specimen			Reference
$P_{\overline{3}}$			
A.africanus Sts	$\bar{X}m$	4.9	Sperber, 1974
	$\bar{X}d$	5.5	" "
A.robustus Kr	$\bar{X}m$	4.5	" "
	$\bar{X}d$	4.5	" "
A. robustus SK	$\bar{X}m$	4.8	" "
	$\bar{X}d$	5.0	" "
Homo sp. SK	1R	5.4	" "
$P_{\overline{4}}$			
A.africanus Sts	$\bar{X}m$	3.4	Sperber, 1974
	$\bar{X}d$	4.7	" "
A.robustus SK	$\bar{X}m$	5.2	" "
	$\bar{X}d$	5.2	" "
$M_{\overline{1}}$			
A.africanus MLD	$\bar{X}m$	5.0	Sperber, 1974
	$\bar{X}d$	5.3	" "
A.robustus SK	$\bar{X}m$	4.7	" "
	$\bar{X}d$	4.7	" "
$M_{\overline{2}}$			
A.africanus Sts	$\bar{X}m$	5.0	Sperber, 1974
	$\bar{X}d$	5.4	" "
A.robustus Kr	$\bar{X}m$	6.4	" "
	$\bar{X}d$	5.3	" "
A.robustus SK	$\bar{X}m$	5.7	" "
	$\bar{X}d$	6.1	" "
$M_{\overline{3}}$			
A.africanus Sts	$\bar{X}m$	5.3	Sperber, 1974
	$\bar{X}d$	6.7	" "
A.robustus Kr	$\bar{X}m$	6.5	" "
	$\bar{X}d$	8.7	" "
A.robustus SK	$\bar{X}m$	6.2	" "
	$\bar{X}d$	7.3	" "
$p\overline{3}$			
A.africanus Sts	$\bar{X}mb$	4.4	Sperber, 1974
	$\bar{X}db$	2.3	" "
	$\bar{X}l$	4.9	" "

L(iii):Root mesiodistal diameter

Specimen				Reference
P^3 (cont.)				
A. robustus	SK	$\bar{X}$mb	4.4	Sperber, 1974
		$\bar{X}$db	3.6	" "
		$\bar{X}$l	6.3	" "
P^4				
A.africanus	Sts	$\bar{X}$mb	4.9	Sperber, 1974
A.robustus	SK	$\bar{X}$mb	4.3	" "
		$\bar{X}$db	3.3	" "
		$\bar{X}$l	6.6	" "
M^1				
A.africanus	MLD	$\bar{X}$mb	4.0	Sperber, 1974
		$\bar{X}$l?	9.0	" "
A.africanus	Sts	$\bar{X}$mb	4.3	" "
		$\bar{X}$db	4.6	" "
		$\bar{X}$l	8.9	" "
A.robustus	SK	$\bar{X}$mb	4.4	" "
		$\bar{X}$db	3.8	" "
		$\bar{X}$l	7.5	" "
M^2				
A.africanus	MLD	$\bar{X}$mb	4.1	Sperber, 1974
		$\bar{X}$db	4.1	" "
		$\bar{X}$l	11.1	" "
A.africanus	Sts	$\bar{X}$mb	4.5	" "
		$\bar{X}$db	4.3	" "
		$\bar{X}$l	9.1	" "
A.robustus	SK	$\bar{X}$mb	4.4	" "
		$\bar{X}$db	4.5	" "
		$\bar{X}$l	10.0	" "
M^3				
A.africanus	MLD	$\bar{X}$mb	4.5	Sperber, 1974
		$\bar{X}$bd	3.5	" "
A.africanus	Sts	$\bar{X}$mb	3.5	" "
		$\bar{X}$db	4.0	" "
		$\bar{X}$l	8.7	" "
A.robustus	SK	$\bar{X}$mb	5.8	" "
		$\bar{X}$db	5.7	" "
		$\bar{X}$l	9.4	" "
Homo sp.		db	4.5	" "
		l	8.7	" "

Appendix M : Statistical summaries for the root and crown dimensions and indices in the fossil hominid groups

M (i) : Neck mesiodistal diameter

M (ii) : Location of bifurcation

M (iii) : Actual root height

M (iv) : Projected root height

M (v) : Root mesiodistal diameter

M (vi) : Height of bifurcation

M (vii) : Root angulation

M (viii) : Crown mesiodistal diameter

M (ix) : Crown buccolingual diameter

M (x) : Location of bifurcation index

M (xi) : Root robusticity

M (xii) : Height of bifurcation index

M (xiii) : Root divergence

M(1) : Neck mesiodistal diameter

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$\bar{I_1}$							
Group B	4.2	0.05	0.1	4.1	4.3	2.3	4
$\bar{I_2}$							
Group A	5	-	-	-	-	-	1
Group B	5.2	-	-	-	-	-	1
Group C	3.5	-	-	-	-	-	1
Group D	4.9	0.36	0.7	4.0	5.5	14.7	4
$\bar{C_1}$							
Group A	6.7	-	-	-	-	-	1
Group B	7.6	-	-	7.1	8.0	-	2
$\bar{P_3}$							
Group A	10.4	-	-	10.1	10.6	-	2
Group B	9.2	0.43	1.1	8.2	10.9	11.6	6
Group C	7.5	0.33	0.7	6.9	8.2	8.8	4
Group D	8.1	0.28	0.7	7.1	8.9	9.0	7
$\bar{P_4}$							
Group A	9.4	0.80	1.6	7.8	11.3	17.0	4
Group B	11.6	0.36	1.3	9.3	13.5	11.5	14
Group C	8.5	0.19	0.5	8.0	9.1	5.4	6
Group D	8.0	0.28	1.0	6.6	9.5	12.0	12
$\bar{M_1}$							
Group A	11.7	0.57	1.4	10.3	13.4	11.9	6
Group B	14.2	0.37	1.2	12.4	15.9	8.6	11
Group C	11.9	0.12	0.2	11.5	12.0	2.0	4
Group D	11.5	0.15	0.5	11.0	12.3	4.0	9
$\bar{M_2}$							
Group A	13.0	0.53	1.2	11.5	14.2	9.1	5
Group B	15.8	0.45	1.5	12.9	17.9	9.4	11
Group C	13.1	-	-	13.0	13.1	-	2
Group D	12.3	0.45	1.3	10.8	14.1	10.3	8
$\bar{M_3}$							
Group A	14.3	0.97	1.9	11.7	16.4	13.6	4
Group B	18.6	0.61	1.9	14.7	20.7	10.3	10
Group C	14.9	-	-	-	-	-	1
Group D	11.9	0.53	1.2	10.6	13.8	9.9	5

M(11) : Location of bifurcation

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$P\frac{-}{3}$							
Group A	4.9	-	-	4.6	5.1	-	2
Group B	4.9	-	-	-	-	-	1
$P\frac{-}{4}$							
Group A	4.6	0.09	0.2	4.5	4.8	3.3	3
Group B	5.7	0.33	0.9	4.4	6.8	15.3	7
Group C	4.2	0.15	0.3	3.8	4.6	8.0	5
$M\frac{-}{1}$							
Group A	5.5	0.10	0.2	5.3	5.8	3.7	4
Group B	6.9	0.17	0.5	6.4	7.4	6.5	7
Group C	6.2	0.12	0.2	6.0	6.4	3.4	3
Group D	5.8	0.14	0.4	5.1	6.5	7.1	9
$M\frac{-}{2}$							
Group A	6.7	0.37	0.8	5.6	7.3	11.2	4
Group B	7.8	0.17	0.5	7.0	8.4	6.3	8
Group C	6.4	-	-	6.4	6.4	-	2
Group D	6.7	0.22	0.6	5.8	7.4	9.5	8
$M\frac{-}{3}$							
Group A	7.6	0.46	0.8	6.8	8.4	10.6	3
Group B	9.2	0.36	0.9	8.4	10.7	9.5	6
Group C	8.4	-	-	-	-	-	1
Group D	6.2	0.13	0.3	5.9	6.5	4.0	4

M(111) : Actual root height

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$I_{\bar{1}}$							
Group B	20.6	-	-	19.6	21.5	-	2
$I_{\bar{2}}$							
Group B	21.7	-	-	-	-	-	1
Group D	20	-	-	-	-	-	1
$C_{\bar{1}}$							
Group A	21.8	-	-	-	-	-	1
Group B	31.2	-	-	29.6	32.7	-	2
Group C	25.4	-	-	-	-	-	1
Group D	23.5	1.09	2.9	19.0	26.6	12.3	7
$2RP_{\bar{3}}m$							
Group A	18.5	-	-	16.8	20.1	-	2
Group B	21.9	-	-	21.0	22.7	-	2
Group C	17.5	1.71	3.0	14.1	19.5	16.9	3
Group D	22.3	1.13	2.0	20.1	23.7	8.7	3
$2RP_{\bar{3}}d$							
Group A	19.0	-	-	17.1	20.8	-	2
Group B	22.5	1.68	2.9	19.6	25.4	12.9	3
Group C	16.9	1.39	2.4	14.3	19.0	14.2	3
Group D	21.8	1.49	2.6	18.9	23.7	11.8	3
$1RP_{\bar{3}}$							
Group D	19.3	1.22	2.4	17.7	22.9	12.6	4
$2RP_{\bar{4}}m$							
Group A	18.5	1.30	2.3	17.1	21.1	12.2	3
Group B	22.2	1.11	3.1	16.7	25.5	14.1	8
Group C	18.1	1.19	2.7	14.8	20.7	14.7	5
Group D	17.4	-	-	-	-	-	1
$2RP_{\bar{4}}d$							
Group A	18.3	2.10	3.6	16.0	22.5	19.9	3
Group B	22.4	0.89	2.8	17.1	26.7	12.6	10
Group C	19.0	1.10	2.5	16.4	21.5	13.0	5
Group D	16.8	-	-	-	-	-	1

M(111) : Actual root height

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$1RP_4^{\bar{}}$							
Group D	22.1	1.14	3.0	16.5	25.5	13.6	7
$M_1^{\bar{}}m$							
Group A	17.0	1.81	3.6	13.8	21.4	21.4	4
Group B	19.5	0.76	2.0	16.8	22.2	10.2	7
Group C	17.2	2.26	3.9	13.5	21.3	22.7	3
Group D	18.4	1.09	2.9	14.0	22.1	15.7	7
$M_1^{\bar{}}d$							
Group A	16.5	1.90	3.8	12.6	21.0	23.0	4
Group B	19.3	1.16	3.1	15.5	23.9	15.9	7
Group C	16.8	2.03	3.5	13.5	20.5	20.9	3
Group D	18.5	0.84	2.2	15.2	21.1	12.0	7
$M_2^{\bar{}}m$							
Group A	18.1	2.54	5.1	13.5	24.6	28.0	4
Group B	20.5	0.93	2.6	16.7	23.5	12.8	8
Group C	18.3	-	-	17.8	18.7	-	2
Group D	19.0	1.08	2.9	14.2	22.2	15.0	7
$M_2^{\bar{}}d$							
Group A	18.0	2.52	5.0	13.3	24.1	28.0	4
Group B	19.9	0.88	2.5	16.4	23.1	12.5	8
Group C	19.3	-	-	18.3	20.2	-	2
Group D	17.0	1.03	2.3	13.7	19.2	13.6	5
$M_3^{\bar{}}m$							
Group A	17.9	2.13	3.7	13.7	20.6	20.6	3
Group B	19.9	0.62	1.4	17.5	20.8	6.9	5
Group D	17.9	-	-	16.4	19.3	-	2
$M_3^{\bar{}}d$							
Group A	18.6	-	-	18.2	19.0	-	2
Group B	18.9	0.35	0.7	18.2	19.6	3.7	4
Group C	15.0	-	-	-	-	-	1
Group D	16.5	-	-	15.0	17.9	-	2

M(iv) : Projected root height

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$I_{\bar{1}}$							
Group B	20.6	-	-	19.6	21.5	-	2
$I_{\bar{2}}$							
Group B	21.4	-	-	-	-	-	1
Group D	15.8	-	-	-	-	-	1
$2RP_{\bar{3}}m$							
Group A	18.5	-	-	16.8	20.1	-	2
Group B	20.1	-	-	20.9	22.5	-	2
Group C	17.3	1.71	3.0	13.9	19.3	17.1	3
Group D	22.1	1.11	1.9	19.9	23.4	8.7	3
$2RP_{\bar{3}}d$							
Group A	19.0	-	-	17.1	20.8	-	2
Group B	22.4	1.71	3.0	19.5	25.4	13.2	3
Group C	16.8	1.35	2.4	14.2	18.8	14.0	3
Group D	21.7	1.43	2.5	18.9	23.5	11.4	3
$1RP_{\bar{3}}$							
Group D	18.5	1.10	2.5	16.0	22.6	13.3	5
$2RP_{\bar{4}}m$							
Group A	18.3	1.14	2.0	17.1	20.6	10.7	3
Group B	22.1	1.06	3.0	16.9	25.1	13.6	8
Group C	18.1	1.19	2.7	14.8	20.7	14.7	5
Group D	17.4	-	-	-	-	-	1
$2RP_{\bar{4}}d$							
Group A	18.3	2.12	3.7	16.0	22.5	20.1	3
Group B	22.1	0.82	2.6	17.1	25.7	11.7	10
Group C	18.9	1.07	2.4	16.4	21.4	12.7	5
Group D	16.8	-	-	-	-	-	1
$1RP_{\bar{4}}$							
Group D	21.4	1.19	3.4	16.5	25.3	15.7	8
$M_{\bar{1}}m$							
Group A	16.7	1.64	3.3	13.7	20.5	19.7	4
Group B	19.5	0.76	2.0	16.7	22.1	10.3	7
Group C	17.1	2.17	3.8	13.4	20.9	22.0	3
Group D	18.8	0.90	2.2	15.3	21.5	11.7	6

M(iv) : Projected root height

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
M_1^-d							
Group A	15.6	1.67	3.3	12.3	18.9	21.4	4
Group B	19.2	1.18	3.1	15.4	23.9	16.3	7
Group C	16.5	2.03	3.5	13.2	20.2	21.2	3
Group D	18.2	0.83	2.2	15.0	20.9	12.1	7
M_2^-m							
Group A	18.1	1.93	4.3	13.1	23.2	23.8	5
Group B	20.3	0.98	2.8	16.1	23.4	13.6	8
Group C	18.2	-	-	17.6	18.7	-	2
Group D	18.5	1.05	2.8	14.0	21.6	15.0	7
M_2^-d							
Group A	17.7	1.97	4.4	12.5	22.3	24.8	5
Group B	19.7	0.91	2.6	16.0	23.0	13.1	8
Group C	18.9	-	-	17.8	19.9	-	2
Group D	16.5	0.99	2.2	13.6	18.9	13.4	5
M_3^-m							
Group A	17.3	1.99	3.4	13.3	19.4	19.9	3
Group B	19.7	0.58	1.3	17.5	20.6	6.5	5
Group D	17.7	-	-	16.3	19.1	-	2
M_3^-d							
Group A	17.8	-	-	17.6	17.9	-	2
Group B	17.8	0.50	1.0	16.9	19.2	5.6	4
Group C	14.1	-	-	-	-	-	1
Group D	16.1	-	-	14.4	17.7	-	2

M(v) : Root mesiodistal diameter

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$C\frac{-}{1}$							
Group A	5.1	-	-	-	-	-	1
Group B	6.7	-	-	6.5	6.9	-	2
$2RP\frac{-}{3}m$							
Group A	3.8	-	-	3.6	4.0	-	2
Group B	4.3	-	-	3.9	4.2	-	2
Group C	4.0	0.32	0.6	3.5	4.6	13.7	3
Group D	5.1	0.23	0.4	4.9	5.6	7.9	3
$2RP\frac{-}{3}d$							
Group A	4.1	-	-	3.9	4.2	-	2
Group B	4.8	0.34	0.6	4.4	5.5	12.1	3
Group C	4.1	0.07	0.1	4.0	4.2	2.8	3
Group D	4.7	0.27	0.5	4.2	5.1	10.0	3
$1RP\frac{-}{3}$							
Group D	6.5	0.39	0.8	5.7	7.5	12.0	4
$2RP\frac{-}{4}m$							
Group A	3.9	0.33	0.6	3.4	4.5	14.7	3
Group B	5.3	0.20	0.6	4.2	5.9	10.4	8
Group C	3.8	0.17	0.4	3.3	4.3	9.7	5
Group D	3.8	-	-	-	-	-	1
$2RP\frac{-}{4}d$							
Group A	4.1	0.52	0.9	3.4	5.1	22.3	3
Group B	5.7	0.15	0.5	4.6	6.2	8.3	10
Group C	4.0	0.28	0.6	3.6	5.1	15.3	5
Group D	6.0	-	-	-	-	-	1
$1RP\frac{-}{4}$							
Group D	6.2	0.39	1.0	5.2	8.2	16.5	7
$M\frac{-}{1}m$							
Group A	4.1	0.16	0.3	3.8	4.5	7.7	4
Group B	5.2	0.28	0.7	4.0	6.3	14.1	7
Group C	4.7	0.12	0.2	4.5	4.9	4.5	3
Group D	4.7	0.24	0.6	4.0	5.6	13.5	7
$M\frac{-}{1}d$							
Group A	4.7	0.47	0.9	4.0	6.0	20.3	4
Group B	5.6	0.19	0.5	4.7	6.2	8.9	7
Group C	4.7	0.18	0.3	4.4	5.0	6.6	3
Group D	4.6	0.08	0.2	4.2	4.8	4.4	7

M(v) : Root mesiodistal diameter

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$M_{\bar{2}}m$							
Group A	4.5	0.24	0.5	4.1	5.2	10.7	4
Group B	6.1	0.25	0.7	5.0	6.8	11.4	8
Group C	5.1	-	-	4.8	5.3	-	2
Group D	4.8	0.13	0.4	4.3	5.4	7.1	7
$M_{\bar{2}}d$							
Group A	5.0	0.32	0.6	4.4	5.6	12.8	4
Group B	6.8	0.27	0.8	5.7	7.8	11.4	8
Group C	5.2	-	-	5.0	5.3	-	2
Group D	4.9	0.26	0.6	4.2	5.8	11.8	5
$M_{\bar{3}}m$							
Group A	5.0	0.29	0.5	4.5	5.5	10.1	3
Group B	6.8	0.37	0.8	6.1	8.1	12.2	5
Group D	5.1	-	-	5.0	5.2	-	2
$M_{\bar{3}}d$							
Group A	5.6	-	-	5.3	5.8	-	2
Group B	7.3	0.38	0.8	6.7	8.4	10.5	4
Group C	6.1	-	-	-	-	-	1
Group D	5.4	-	-	5.0	5.8	-	2

M(v1) : Height of bifurcation

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$2RP_{\bar{3}}$							
Group A	5.2	-	-	5.0	5.3	-	2
Group B	7.5	-	-	-	-	-	1
$2RP_{\bar{4}}$							
Group A	5.1	0.09	0.2	5.0	5.3	3.0	3
Group B	5.8	0.45	1.2	4.6	7.5	20.5	7
Group C	6.8	0.93	2.1	4.7	9.8	30.9	5
$M_{\bar{1}}$							
Group A	4.1	0.50	1.0	3.1	5.4	24.3	4
Group B	5.1	0.28	0.7	4.2	6.4	14.6	7
Group C	3.7	0.24	0.4	3.4	4.2	11.2	3
Group D	4.8	0.42	1.3	3.5	7.4	27.6	10
$M_{\bar{2}}$							
Group A	3.7	0.55	1.1	2.5	5.0	29.9	4
Group B	4.7	0.40	1.1	2.6	6.1	24.3	8
Group C	5.6	-	-	5.2	6.0	-	2
Group D	5.2	0.56	1.7	2.9	8.1	32.2	9
$M_{\bar{3}}$							
Group A	4.8	1.17	2.0	2.5	6.4	42.5	3
Group B	4.8	0.35	0.9	4.0	6.1	17.7	6
Group C	5.0	-	-	-	-	-	1
Group D	5.5	0.99	2.0	3.5	8.2	36.4	4

M(vii) : Root angulation

	$\bar{X}$	S.E.	S.D.	min	max	N
$I\frac{-}{1}$						
Group B	+3	-	-	+2	+3	2
$I\frac{-}{2}$						
Group B	+9	-	-	-	-	1
$2RP\frac{-}{3}m$						
Group A	+1	-	-	-	-	2
Group B	-2	-	-	-3	0	2
Group C	-7	1.00	1.7	-8	-5	3
Group D	-7	0.33	0.6	-8	-7	3
$2RP\frac{-}{3}d$						
Group A	-2	-	-	-3	-1	2
Group B	-3	1.67	2.9	-6	-1	3
Group C	-8	0.88	1.5	-9	-6	3
Group D	-6	0.58	1.0	-7	-5	3
$1RP\frac{-}{3}$						
Group D	-2	2.10	4.2	-8	+2	4
$2RP\frac{-}{4}m$						
Group A	+4	3.38	5.9	0	+11	3
Group B	+1	1.26	3.1	-2	+6	6
Group C	+2	0.87	2.0	-1	+3	5
Group D	0	-	-	-	-	1
$2RP\frac{-}{4}d$						
Group A	-3	1.53	2.7	-5	0	3
Group B	-4	1.77	4.7	-12	+1	7
Group C	-3	1.21	2.7	-7	0	5
Group D	-2	-	-	-	-	1
$1RP\frac{-}{4}$						
Group D	-4	1.33	3.5	-8	0	7
$M\frac{-}{1}m$						
Group A	0	3.35	6.7	-9	+7	4
Group B	+1	1.04	2.8	-2	+5	7
Group C	-4	2.60	4.5	-8	+1	3
Group D	-5	1.60	4.2	-11	+1	7
$M\frac{-}{1}d$						
Group A	-16	3.95	7.9	-23	-5	4
Group B	-6	1.23	3.3	-9	-1	7
Group C	-9	0.88	1.5	-11	-8	3
Group D	-10	0.72	1.9	-12	-8	7

M(vii) : Root angulation

	$\bar{X}$	S.E.	S.D.	min	max	N
$M_{\bar{2}}m$						
Group A	-10	1.44	2.9	-13	-6	4
Group B	-5	1.44	4.1	-11	0	8
Group C	-3	-	-	-7	+2	2
Group D	-10	1.02	2.7	-14	-6	7
$M_{\bar{2}}d$						
Group A	-16	1.78	3.6	-19	-11	4
Group B	-8	1.37	3.9	-15	-2	8
Group C	-11	-	-	-14	-8	2
Group D	-13	1.36	3.1	-17	-9	5
$M_{\bar{3}}m$						
Group A	-9	5.04	8.7	-16	+1	3
Group B	-4	0.81	1.8	-6	-1	5
Group D	-6	-	-	-7	-4	2
$M_{\bar{3}}d$						
Group A	-14	-	-	-20	-8	2
Group B	-19	2.12	4.2	-23	-13	4
Group C	-19	-	-	-	-	1
Group D	-14	-	-	-18	-9	2

M(viii) : Crown mesiodistal diameter

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$I_{\bar{1}}$							
Group B	5.3	0.18	0.5	4.5	5.6	8.5	6
Group D	6.4	0.03	0.1	6.4	6.5	0.9	3
$I_{\bar{2}}$							
Group B	6.5	0.10	0.2	6.2	6.6	3.0	4
Group D	7.4	0.12	0.3	7.1	7.7	3.5	5
$C_{\bar{1}}$							
Group B	7.8	0.22	0.5	7.3	8.6	6.4	5
Group D	9.0	0.28	0.7	7.6	9.9	8.1	7
$P_{\bar{3}}$							
Group A	11.4	-	-	-	-	-	1
Group B	11.1	0.34	0.8	10.1	12.1	6.8	5
Group C	8.9	-	-	-	-	-	1
Group D	9.8	0.19	0.5	9.0	10.6	5.5	8
$P_{\bar{4}}$							
Group A	11.1	0.59	1.2	10.0	12.2	10.7	4
Group B	13.5	0.35	1.2	11.4	15.0	8.7	11
Group C	9.7	0.35	0.6	9.1	10.3	6.2	3
Group D	9.8	0.33	1.0	8.6	11.5	10.1	9
$M_{\bar{1}}$							
Group A	13.4	0.47	1.0	12.6	15	7.8	5
Group B	16.3	0.43	1.1	14.8	17.8	7.0	7
Group C	13.7	0.18	0.4	13.2	14.0	2.6	4
Group D	13.4	0.28	0.8	12.5	14.6	6.0	8
$M_{\bar{2}}$							
Group A	14.7	0.41	1.0	13.0	16	6.8	6
Group B	18.9	0.54	1.6	16.6	20.8	8.6	9
Group C	14.6	-	-	14.1	15	-	2
Group D	14.2	0.41	1.1	13.0	15.7	7.7	7
$M_{\bar{3}}$							
Group A	16.0	0.93	2.1	13.6	19.0	13.0	5
Group B	19.7	0.56	1.5	17.7	21.3	7.5	7
Group C	16.8	-	-	-	-	-	1
Group D	14.6	0.58	1.3	13.2	15.9	8.9	5

M(ix) : Crown buccolingual diameter

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$I_{\bar{1}}$							
Group B	6.9	0.35	0.9	6.2	8.0	12.4	6
Group D	6.8	0.12	0.2	6.6	7.0	3.1	3
$I_{\bar{2}}$							
Group B	7.0	0.55	1.0	6.4	8.1	13.6	3
Group D	7.4	0.11	0.3	7.0	7.6	3.4	5
$C_{\bar{1}}$							
Group B	9.2	0.25	0.6	8.2	9.7	6.8	6
Group D	9.4	0.52	1.0	7.9	10.2	11.1	4
$P_{\bar{3}}$							
Group A	10.1	-	-	-	-	-	1
Group B	13.2	0.35	0.9	11.5	13.9	6.5	6
Group C	8.0	-	-	-	-	-	1
Group D	10.2	0.42	1.2	8.7	12.5	11.6	8
$P_{\bar{4}}$							
Group A	10.9	-	-	10.7	11.0	-	2
Group B	14.4	0.53	1.7	11.8	16.5	11.5	10
Group C	8.1	-	-	-	-	-	1
Group D	10.7	0.15	0.4	9.9	11.1	4.1	9
$M_{\bar{1}}$							
Group A	12.1	0.29	0.5	11.5	12.4	4.1	3
Group B	14.8	0.53	1.3	13.0	16.0	8.8	6
Group C	12.2	0.82	1.4	10.6	13.2	11.6	3
Group D	11.8	0.29	0.8	10.8	12.8	7.1	8
$M_{\bar{2}}$							
Group A	12.7	0.61	1.1	11.6	12.9	8.3	3
Group B	17.0	0.62	1.9	14.2	19.0	11.0	9
Group C	11.7	-	-	-	-	-	1
Group D	12.9	0.46	1.2	11.7	13.7	9.4	7
$M_{\bar{3}}$							
Group A	12.5	0.71	1.2	11.5	13.9	9.9	3
Group B	17.0	0.55	1.5	15.6	19.0	8.6	7
Group C	14.9	-	-	-	-	-	1
Group D	13.1	0.51	1.2	12.1	14.4	8.8	5

M(x) : Location of bifurcation index

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$P_{\bar{3}}$							
Group A	46.9	-	-	45.6	48.1	-	2
Group B	53.3	-	-	-	-	-	1
$P_{\bar{4}}$							
Group A	53.4	3.32	5.8	47.5	50.0	10.8	3
Group B	48.0	1.73	4.6	40.3	54.4	9.5	7
Group C	49.3	1.40	3.1	47.2	54.8	6.3	5
$M_{\bar{1}}$							
Group A	50.0	1.90	3.8	44.6	53.4	7.6	4
Group B	47.8	0.90	2.4	43.0	50.0	5.0	7
Group C	52.3	0.58	1.0	51.3	53.3	1.9	3
Group D	50.8	1.09	3.3	46.4	55.1	6.5	9
$M_{\bar{2}}$							
Group A	52.5	1.52	3.0	48.7	55.1	5.8	4
Group B	47.5	0.57	1.6	44.8	49.7	3.4	8
Group C	49.1	-	-	48.9	49.2	-	2
Group D	54.1	1.27	3.6	47.5	58.5	6.6	8
$M_{\bar{3}}$							
Group A	54.0	2.09	3.6	51.2	58.1	6.7	3
Group B	48.9	1.20	2.9	44.4	52.5	6.0	6
Group C	56.4	-	-	-	-	-	1
Group D	52.3	2.58	5.2	47.1	59.4	9.9	4

M(x1) : Root robusticity

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$C_{\bar{1}}$							
Group A	23.4	-	-	-	-	-	1
Group B	21.6	-	-	21.1	22.0	-	2
$2RP_{\bar{3}}m$							
Group A	20.7	-	-	19.9	21.4	-	2
Group B	18.0	-	-	17.2	21.9	-	2
Group C	23.6	3.03	5.2	18.0	28.4	22.2	3
Group D	23.2	2.34	4.1	20.7	27.9	17.4	3
$2RP_{\bar{3}}d$							
Group A	21.5	-	-	20.2	22.8	-	2
Group B	21.6	0.58	1.0	20.5	22.5	4.7	3
Group C	24.7	1.74	3.0	22.1	28.0	12.2	3
Group D	21.7	0.25	0.4	21.4	22.2	2.0	3
$1RP_{\bar{3}}$							
Group D	33.8	3.17	6.3	26.6	41.9	18.8	4
$2RP_{\bar{4}}m$							
Group A	20.9	0.48	0.8	19.9	21.4	4.0	3
Group B	24.1	0.97	2.7	19.2	27.7	11.3	8
Group C	21.6	1.99	4.4	17.9	29.1	20.6	5
Group D	21.8	-	-	-	-	-	1
$2RP_{\bar{4}}d$							
Group A	22.2	0.45	0.8	21.3	22.7	3.5	3
Group B	25.7	0.56	1.8	23.2	28.0	6.9	10
Group C	21.6	2.35	5.3	17.7	30.4	24.3	5
Group D	35.7	-	-	-	-	-	1
$1RP_{\bar{4}}$							
Group D	28.9	2.80	7.4	21.6	39.1	25.6	7
$M_{\bar{1}}m$							
Group A	25.0	2.48	5.0	18.2	29.6	19.9	4
Group B	26.7	1.28	3.4	23.8	33.9	12.6	7
Group C	27.8	2.99	5.2	23.0	33.3	18.6	3
Group D	24.3	0.83	2.0	22.1	27.1	8.4	6
$M_{\bar{1}}d$							
Group A	28.7	2.50	5.0	21.9	33.0	17.4	4
Group B	29.3	0.92	2.4	25.9	32.3	8.3	7
Group C	28.4	2.37	4.1	24.4	32.6	14.5	3
Group D	25.0	0.87	2.3	21.8	27.6	9.3	7

M(x1) : Root robusticity

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$M_{\bar{2}}m$							
Group A	26.3	3.37	6.8	16.7	31.9	25.7	4
Group B	29.8	0.90	2.6	26.7	34.5	8.6	8
Group C	27.7	-	-	27.0	28.3	-	2
Group D	25.9	1.53	4.0	22.0	33.1	15.6	7
$M_{\bar{2}}d$							
Group A	28.7	2.24	4.5	22.8	33.1	15.6	4
Group B	34.1	0.78	2.2	31.2	36.6	6.5	8
Group C	26.9	-	-	24.8	29.0	-	2
Group D	29.2	1.79	4.0	25.5	34.3	13.7	5
$M_{\bar{3}}m$							
Group A	28.7	4.02	7.0	21.9	35.8	24.2	3
Group B	34.1	1.95	4.4	29.5	37.7	12.8	5
Group D	28.8	-	-	25.9	31.7	-	2
$M_{\bar{3}}d$							
Group A	29.9	-	-	27.9	31.9	-	2
Group B	38.6	2.54	5.1	35.7	46.2	13.2	4
Group C	40.7	-	-	-	-	-	1
Group D	33.3	-	-	27.9	38.7	-	2

M(xii) : Height of bifurcation index

	$\bar{X}$	S.E.	S.D.	min	max	C.V.	N
$2RP_{\bar{3}}$							
Group A	27.4	-	-	25.5	29.2	-	2
Group B	33.3	-	-	-	-	-	1
$2RP_{\bar{4}}$							
Group A	27.4	1.93	3.4	23.6	29.8	12.2	3
Group B	26.7	1.76	4.3	18.8	30.6	16.1	6
Group C	36.2	5.05	11.3	22.1	53.0	31.3	5
$M_{\bar{1}}$							
Group A	24.5	0.85	1.7	22.6	26.3	7.0	4
Group B	25.7	1.14	3.0	20.6	28.7	11.7	7
Group C	22.3	1.61	2.8	20.1	25.4	12.5	3
Group D	27.8	1.89	4.6	23.3	34.4	16.7	6
$M_{\bar{2}}$							
Group A	20.7	0.62	1.3	19.1	21.8	6.0	4
Group B	23.2	2.12	6.0	11.3	31.1	25.9	8
Group C	29.7	-	-	29.2	30.2	-	2
Group D	29.6	0.54	1.2	28.6	31.6	4.1	5
$M_{\bar{3}}$							
Group A	26.7	4.18	7.2	18.8	33.0	27.1	3
Group B	23.2	1.49	3.3	19.5	26.7	14.4	5
Group D	36.2	-	-	29.5	42.9	-	2

M(xiii) : Root divergence

	$\bar{X}$	S.E.	S.D.	min	max	N
$2RP_{\bar{3}}$						
Group A	+3	-	-	+2	+4	2
Group B	+2	-	-	+1	+3	2
Group C	+1	1.76	3.1	-2	+4	3
Group D	-1	0.33	0.6	-2	-1	3
$2RP_{\bar{4}}$						
Group A	+7	2.03	3.5	4	+11	3
Group B	+5	2.38	5.8	-3	+11	6
Group C	+5	1.92	4.3	-1	+10	5
Group D	-2	-	-	-	-	1
$M_{\bar{1}}$						
Group A	+16	3.28	6.6	+7	+22	4
Group B	+6	1.94	5.1	0	+14	7
Group C	+6	2.96	5.1	0	+10	3
Group D	+5	1.78	4.4	0	+11	6
$M_{\bar{2}}$						
Group A	+6	0.95	1.9	+5	+9	4
Group B	+3	1.06	3.0	-2	+7	8
Group C	+9	-	-	+7	+10	2
Group D	+3	0.95	2.1	0	+6	5
$M_{\bar{3}}$						
Group A	+7	-	-	+4	+9	2
Group B	+15	2.29	4.6	+9	+20	4
Group D	+8	-	-	+2	+14	2